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Featuring

Davis Bridge Hydro-Electric Development

Dorchester Rapid Transit Extension

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Volume XII JANUARY, 1925 Number 1

THE NEW ENGLAND POWER COMPANY DAVIS BRIDGE DEVELOPMENT

By A. C. Eaton,* Member, Boston Society of Civil Engineers

(Presented December 17, 1924)

Growth of the New England Power System

By way of creating a proper setting for a description of this 60,000 h. p. plant, it seems best first to outline briefly the growth of the New England Power System. While this growth has been fairly rapid, yet it has developed along perfectly natural lines when considered in the light of our changing conditions. Our New England industries were first developed through the use of water powers. They outgrew this supply of power and continued to expand by supplementing that power with individual steam plants. The New England Power System was started with the idea of furnishing New England industries with hydro-electric power. Originally started as a single plant at Vernon on the Connecticut River in 1909, with lines to deliver its power to Brattleboro, Keene, Worcester and other places, it maintained itself up to 1917 as a hydro-electric system with less than 4% steam relay by additional plants on the Deerfield River.

With the war came greatly increased demand for power and this demand was met by additional connections with sources of steam power. Thus the superpower idea and how such a system develops has been demonstrated in New England the past few years. The system is now developing along the lines of interconnected hydro and steam sources of power which works to the economic advantage of both the steam and hydro plants.

The transmission line system has been growing during the past fifteen years; the first line to be built was a double-circuit 66,000-volt line from the Vernon plant to Gardner, Fitchburg, Clinton and Worcester, with single circuits to Brattleboro and Keene. With the starting o the Deerfield River plants, the second double-circuit line was built from the Deerfield River to Millbury, with connecting lines to North Adams and Vernon. Shortly after, high-tension lines were extended to Providence and still later to Norwich, Conn., Fall River, Boston, Nashua Bellows Falls and Bennington. Last year the 110,000-volt line was built connecting the new Davis Bridge plant with Millbury, and another line connecting the Deerfield River system with the Adirondack Power Company system at Albany. The system now includes about 600 miles o high-tension line, half of which is of double-circuit construction.

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* Hydraulic Engineer, Power Construction Company, Worcester, Mass.

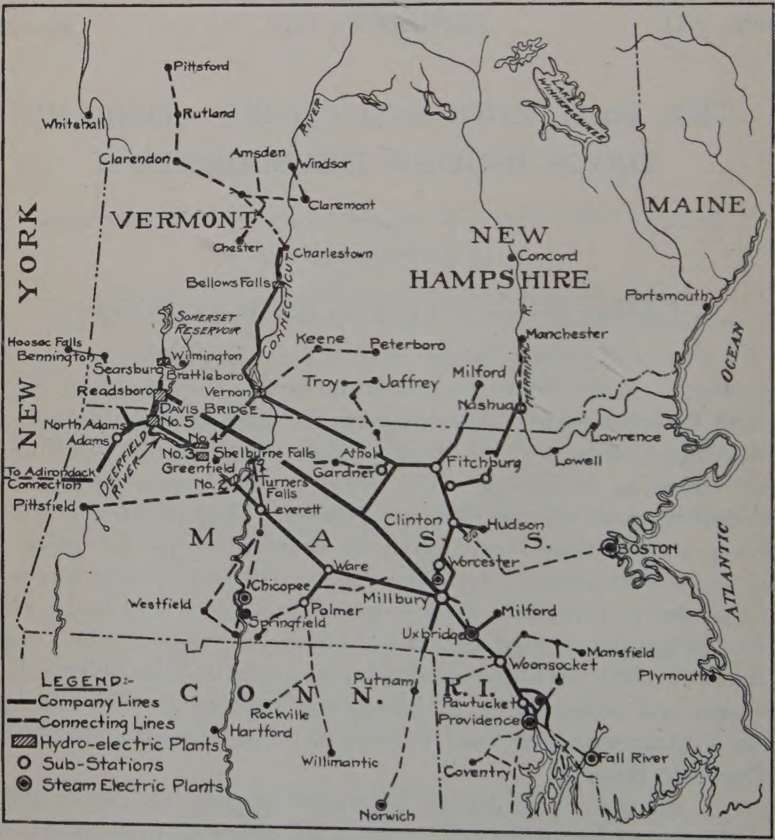
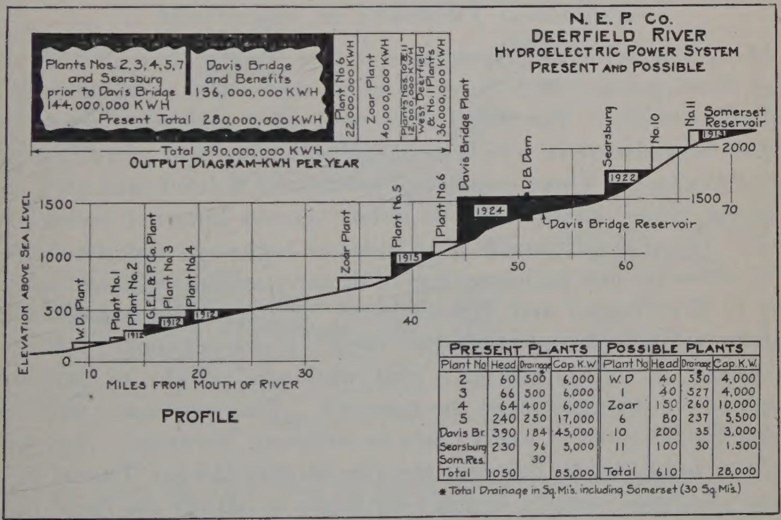


Fig. 1. — New England Power System

The Vernon plant of 28,000 h. p. was completed in 1909. In 1912 plants Nos. 2, 3 and 4, on the Deerfield River near Shelburne Falls, were put into operation with 30,000 h. p. The Somerset reservoir at the head waters of the Deerfield, with a 2,500,000,000 cubic foot storage, was completed in 1913. In January, 1915, plant No. 5 at Hoosac Tunnel went into operation with 24,000 h. p. capacity. A temporary plant of 4,000 h. p. was completed near Readsboro, Vt., in 1916. This ended the hydro construction until after the war.

In 1921 the capacity of the Vernon plant was increased to 40,000 h. p. by adding two modern single-runner units. Early in 1922 a single unit station went into operation at Searsburg on the Deerfield River with a capacity of about 6,000 h. p. The same year work was started on the Davis Bridge project, and this plant went into operation in May, 1924. Thus, in fourteen years the system has grown to an output of 570,000,000 Kw.H. in 1923, with a recent maximum hour of 151,000 Kw.H. and day of 2,300,000 Kw.H. The gross income of the system has increased from about $250,000 in 1910 to $7,300,000 in 1923.


N. E. P. Co.
DEERFIELD RIVER
HYDROELECTRIC POWER SYSTEM
PRESENT AND POSSIBLE
Plants Nos. 2, 3, 4, 5, 7 and Searsburg prior to Davis Bridge 144,000,000 KWH
Davis Bridge and Benefits 136,000,000 KWH
Present Total 280,000,000 KWH
Plant No 6 22,000,000 KWH
Zoar Plant 40,000,000 KWH
Plants Nos 10 & 11 12,000,000 KWH
West Deerfield & No. 1 Plants 36,000,000 KWH
Total 390,000,000 KWH
OUTPUT DIAGRAM-KWH PER YEAR
ELEVATION ABOVE SEA LEVEL
1500
1000
500
0
W.D. Plant
Plant No. 1
Plant No. 2
G.E.L. & P. Co. Plant
Plant No. 3
Plant No. 4
1912
1912
1912
Zoar Plant
Plant No. 5
1915
Plant No. 6
Davis Bridge Plant
1924
D.B. Dam
Davis Bridge Reservoir
Searsburg
1922
No. 10
No. 11
Somerset Reservoir
1913
2000
1500
10
20
30
40
50
60
70
MILES FROM MOUTH OF RIVER
PROFILE

PRESENT PLANTS				POSSIBLE PLANTS			
Plant No	Head	Drainage *	Cap. K.W	Plant No	Head	Drainage *	Cap. K.W.
2	60	500	6,000	W. D	40	550	4,000
3	66	500	6,000	1	40	527	4,000
4	64	400	6,000	Zoar	150	260	10,000
5	240	250	17,000	6	80	237	5,500
Davis Br.	390	184	45,000	10	200	35	3,000
Searsburg	230	96	5,000	11	100	30	1,500
Som. Res.		30					
Total	1050		85,000	Total	610		28,000

* Total Drainage in Sq. Mi's. including Somerset (30 Sq. Mi's.)

FIG. 2

The Deerfield River has played an important part in this growth. Of the total drop of 2,000 ft., there is now developed 1,050 ft. Rights are owned by the company for the development of 610 ft. more, leaving about 300 ft. uneconomical to develop. When completed, this stream will have an installed capacity of 110,000 Kw., with an annual output o 400,000,000 Kw.H. These results are obtained on a stream with a drainage area of 550 square miles.

The Somerset dam completely regulates the run-off from 30 square miles of drainage. The Davis Bridge reservoir will almost completely regulate the 150 square miles of drainage between the Somerset dam and the Davis Bridge dam. The lower Deerfield plants make the most of the flood flows below the Davis Bridge dam, while the big reservoirs are collecting the flood run-off of the upper river for later use.

Incidental Problems of Magnitude

Many obstacles were overcome in the construction of the Davis Bridge development which do not present themselves in wilder and less populated sections. The 2,200 acres of flooded area was largely composed of farms, some of which were settled under land grants from the King of England. Three cemeteries within the flooded area and one a the power house, containing altogether several hundred bodies, wer moved. The discontinuance of 14 miles of highways and the substitution of necessary new highways had to be satisfactorily adjusted with th towns of Wilmington and Whitingham. A paper box manufacturin company had to be bought to obtain the 75 ft. of head controlled by it a Readsboro. A 50-ton capacity pulp mill was bought to permit th flowage of the upper 40 ft. of the reservoir. This purchase carried wit it some 40,000 acres of wood lands in southern Vermont. And finall it became necessary to buy outright the 24-mile Hoosac Tunnel & Wilmington Railroad running through the basin to permit the relocation o some 9 miles of its track without undue complications. These feature combined with engineering and construction details made the projec of considerable interest, not only to the engineering profession but als to the general public.

General Scheme of Development

The Davis Bridge development was proposed in 1910 as the firs development on the Deerfield River. The scheme finally adopted calle for a dam 20 ft. higher in elevation than was originally proposed, and th plant water capacity is 1,500 sec. ft. rather than the original propose capacity of 1,000 sec. ft. This greater capacity is due to the change i industrial conditions which calls for shorter working hours and great dependable peak capacities. The idea of the high dam and the large r ulting storage has always been considered a part of the ultimate Deerield development.

While many studies of the project had been made during the period of some ten years, it was late in 1921 before details were fixed with reference to the location and height of the dam, the method of handling the river flow during construction and the type of spillway. It was the early summer of 1922 before the location of the power house was definitely decided.

The problem finally shaped up in the form of an earth dam with a diversion tunnel handling the river flow, a circular spillway located upstream from the dam and discharging through a tunnel, an intake tower to control the flow to a power tunnel, a power tunnel cutting off the bend in the river, thus doubling the available head, a surge tank of unusual height because of the 90 ft. drawdown for storage use, penstocks with valve control both at the upper end and at the wheel inlet, and a power house with high-tension transformers and switching stations of outdoor type adjacent to the power house.

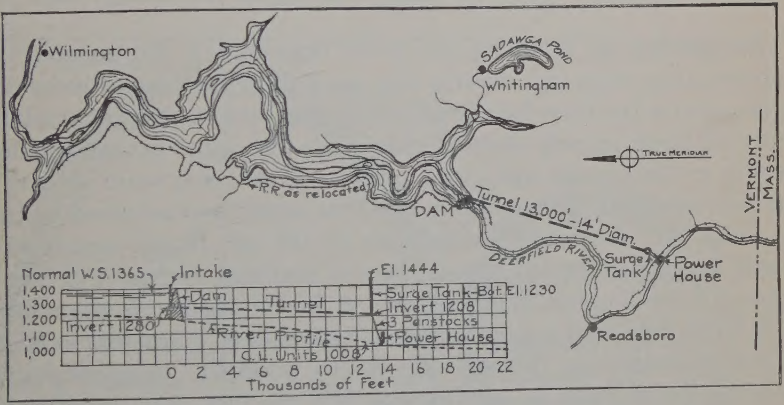


FIG. 3. — GENERAL PLAN OF DEVELOPMENT

CONSTRUCTION CAMPS

The Davis Bridge work was located about equidistant and some 25 miles from Greenfield, North Adams, Brattleboro and Bennington, places which could be used as supply bases. Readsboro and Wilmington, each with a few hundred inhabitants, were within about 10 miles by highway. The location, therefore, required that camps and storehouses should be built to house and feed the workmen. The first camp was built at the dam site with a capacity of 200 men during the fall of 1921. This was the headquarters camp during the life of the job and was increased to a 450-man capacity during the winter. This camp included the office, top mess, storehouses, hospital, general mess and bunk houses for the men, all equipped with water, sewerage, lighting and central heating plant. During the season of 1922 sub-contractors built additional camps, and the season of 1923 found seven camps up and down the valley housing upward of 1,200 men.

DIVERSION TUNNEL TO HANDLE RIVER DURING CONSTRUCTION OF DAM

The problem of handling the river flow during the construction period extending over two seasons was one calling for careful judgment. Flow records for the river for the preceding fourteen years were available. A study of these records showed that while the usual period for flood flows was in the spring, yet other periods of the year were subject to real floods, and that the maximum flood on record had occurred in July, 1915. The 1915 flood had a maximum of 135 sec. ft. per square mile. This rate applied to the 154 square miles of drainage, exclusive of Somerset, gave a flood of about 20,000 sec. ft. A flow of about this size under a head of 70 ft. indicated a size equivalent to a 22½ ft. diameter circle, and after due consideration this size was finally adopted. Another feature influencing the decision to use this size was the fact that the diversion had to pass through a spring break-up, and while open water conditions might warrant a somewhat smaller conduit, the danger of a possible plugging by ice and débris demanded a generous size.

With the question of size determined, the study turned to the question of location. Earlier studies had contemplated the use of a reinforced concrete conduit running under the dam, but there seemed to be too many unknown factors in the design of a conduit of this size for this location, such as the possible variation of the character of the earth foundation, the unknown loads and the possibility of leakage along the concrete surfaces. Also, the use of a conduit would have meant serious delay in starting work and probably a full year's time in the completion of the project, so the conduit plan was abandoned in favor of the tunnel.

Except for investigation work, the first large item of construction to be started was the diversion tunnel, which was let to the Rollin Construction Corporation the latter part of January, 1922. This tunnel enters the left-hand side of the valley just above the upper toe of the dam, and after a sweep of 100 degrees comes into a tangent which nerges below the dam. Speed was a very vital item on this work and ı order to get under ground as quickly as possible, shafts were sunk at ıe location of the portals and approaches cut out at a later date. A ıaft was also sunk which was later enlarged to form the spillway waste-ay. Through a horizontal section near the bottom, this shaft connected ith the tunnel location near the half-way point, and excavation was ırried on in both directions from this point. As soon as space was vailable, steam shovels operating on air were placed in the two end orkings. Muck was loaded into skips placed on trucks and hauled to ıe shafts by mules. The upper 300 ft. of the tunnel was through a lacial drift formation overlying a sloping ledge, and had a marked

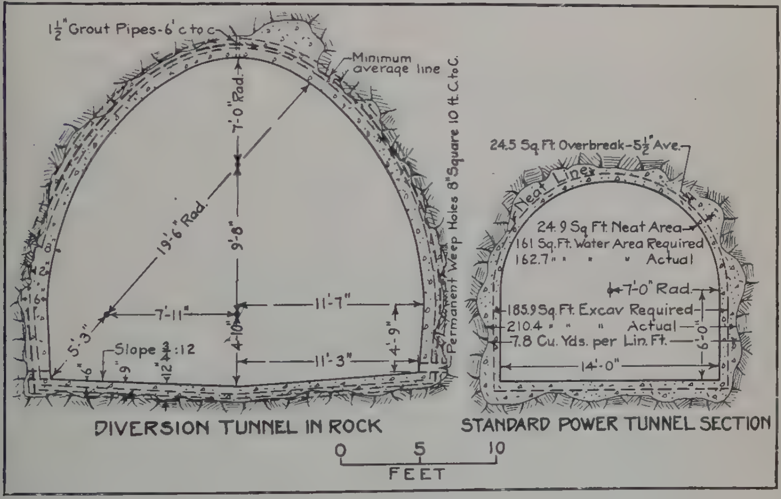

1½" Grout Pipes-6' c to c
Minimum average line
Permanent Weep Holes 8" Square 10 ft. C. to C.
7'-0" Rad.
19'-6" Rad.
9'-8"
11'-7"
7'-11"
4'-10"
4'-9"
11'-3"
5'-3"
Slope ¾:12
6"
9"
12¾"
DIVERSION TUNNEL IN ROCK
24.5 Sq. Ft. Overbreak-5½" Ave.
Neat Line
24.9 Sq. Ft. Neat Area
161 Sq. Ft. Water Area Required
162.7 " " " Actual
7'-0" Rad.
185.9 Sq. Ft. Excav Required
210.4 " " " Actual
7.8 Cu. Yds. per Lin. Ft.
14'-0"
STANDARD POWER TUNNEL SECTION
0
5
10
FEET

Fig. 4

ndency to slide bodily. This section was completely timbered with 2 in. by 12 in. frames on 4 ft. centers covered with 3-in. plank. In the dge section no timbering was required. The ledge in this region is ostly a hard and tough mica schist which had a tendency to break rger than convenient for handling with a steam shovel. The average ıte of excavation was 31 ft. per heading for a fourteen-shift week. The ıte in the earth section with hand mucking was 33 ft. per week; with ıovel mucking, 56 ft. per week. In the ledge section, the rate with hand ucking was 16 ft. per week; with shovel mucking, 35 ft. per week. he average amount of solid rock per week per heading was about 550 ıbic yards. The total length of this tunnel from portal to portal is 528 ft.

The portal headings were turned about February 10, 1922. The north section was holed through on July 14 and the south section the following day. The concreting of the roof followed the excavation closely. Timber forms were used through the earth section and had a true circular shape. Through the rock section Blaw-Knox steel forms were used which had a horseshoe shape. Concrete was mixed at a central plant, transported to the shafts by cars and dumped into hoppers. From the hoppers it was blown into the forms through a 6-in pipe line. This method proved very satisfactory and caused a minimum interference with the mucking. After the completion of the walls and roof, the invert was cleaned and the floor laid. Water was turned through the tunnel on September 17, 1922, which was about 7½ months after the letting of the contract.

This tunnel handled the river flow from September, 1922, until the middle of February, 1924, at which time the concrete plug and small by-pass valves were placed. This closure is in the form of a concrete plug 9 ft. thick located in the by-pass tunnel about 650 ft. from the upstream end. At the time the excavation was made a circumferential groove was cut in the ledge 9 ft. long and 4 ft. greater than the normal section of the tunnel. The general procedure for making the closure was to place a 4-ft. double, extra heavy, cast-iron pipe through the area of the plug. On the lower end of this pipe was placed a disc-arm valve with the disc in open position. This cast-iron pipe extended upstream from the plug a distance of about 15 ft. Near the upper end of this pipe a diversion bulkhead was erected, supported by vertical 18-in. "I" beams and grooves in the sides of the tunnel lining. This bulkhead was carried nearly to the top of the tunnel section, thus providing sufficient head to force the river flow through the 4-ft. pipe. While it had been hoped the flow of the river could be held to 15 or 20 sec. ft. during the installation of this pipe, it actually worked out that the flow did not drop below 60 sec. ft. Placing the 4-ft. pipe and bulkhead during February proved to be a disagreeable detail, but in three days was accomplished, with no mishap. As soon as the water was turned through the 4-ft. pipe the area of the plug was pumped out, cleaned and concrete forms built. Prior t all this an 8-in. well drill hole had been driven from the surface abou 125 ft. above to the center of the concrete plug. When forms wer ready, concrete was mixed at the surface above and shot down the 8-in hole into the forms. This plug contained about 240 yards of concret and was poured in two lifts on two consecutive days. On the third da grout was poured into the 8-in. hole to give the final seal.

Inasmuch as the river flow passed through the 4-ft. pipe for about month after the closure, it seemed necessary to place a rack at the uptream end of the by-pass tunnel. This rack is made up of flat iron bars vith a spacing of about 3 inches. The supports for this rack are in the orm of angle arches with a radius of 28 ft. running from side to side of he portal. The 4-ft. by-pass valve was closed on March 22, 1924, and he reservoir was full and started to spill May 4.

Circular Spillway

A straight spillway of the usual type 500 ft. long at Davis Bridge vould have required a location along the contour as the valley at the dam s steep on both sides. The only feasible location for such a spillway eemed to be upstream from the dam, with the water spilling into a hannel, which in turn would have been carried by the end of the earth lam and down the side of the valley to the old river bed. Because of estimated cost, the uncertainty of probable capacity and the fact that he diversion tunnel had been decided upon, the straight spillway was abandoned in favor of a circular spillway, discharging into a vertical shaft which led to the lower end of the diversion tunnel.

The spillway as finally built is 160 ft. in diameter and symmetrical about a vertical axis. It has been named the "morning-glory" spillway because of its shape. Its diameter decreases from 160 ft. at the crest to 22½ ft. at a point 70 ft. below the crest. This 22½-ft. shaft extends down another 100 ft. where it takes a right angle sweep and enters the lower end of the diversion tunnel on a tangent. After the completion of the lam and the closure of the diversion tunnel above the junction with the spillway shaft, the lower end of the big tunnel became a wasteway for the spillway.

Sixteen radial concrete piers which extend 10 ft. above the concrete spillway crest serve the double purpose of carrying a bridge from which lashboards can be operated and straightening the lines of flow as the vater passes over the crest, thus materially reducing agitation as the vater comes together in the throat of the shaft.

The spillway is located about 350 ft. upstream from the center line of the dam and on the left side of the valley. The structure is located entirely on ledge, with the uphill half and approach channels located on an area excavated from solid ledge, while the downhill side of the structure is formed by cut-off wall on a radius of 54 ft. from the center line of the vertical shaft and radial concrete piers extending therefrom supporting a heavy concrete apron. The approach channels on the upper side of the structure are in the form of a double scroll with the point at the uphill side. These channels were proportioned to give a mean velocity of about 5 ft. per second, with a discharge of about 30,000 sec. ft., or 8 ft.

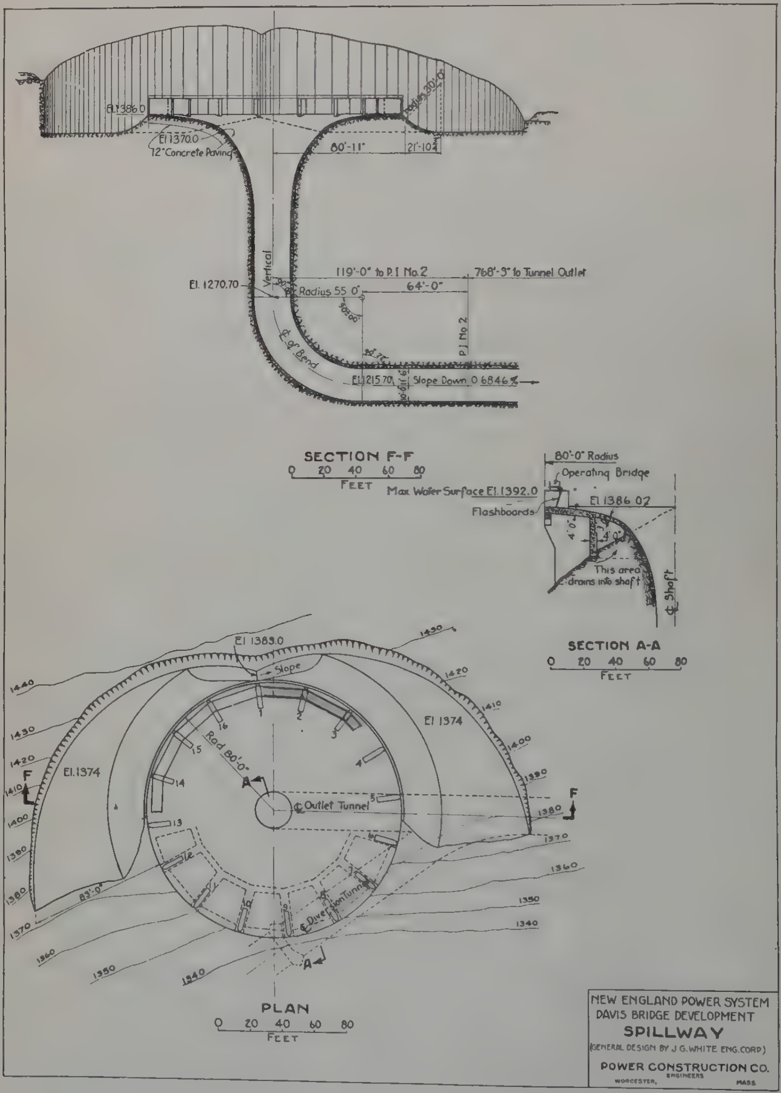


FIG. 5

over the crest. This type of structure was proposed by the consulting engineers for the project, the J. G. White Engineering Corporation.

The details of design were worked out jointly by the Power Company and the J. G. White Corporation. Because of the great importance of the structure, a model was made on a ratio of 1 to 36, and tested in a flume constructed for the purpose at Whitingham near the site of the work. The results of these tests checked rather remarkably with the computations of the design. The details of the hydraulic design and the results of the model tests have been published by Mr. Ford Kurtz of the J. G. White Engineering Corporation in the December, 1923, Proceedings of the American Society of Civil Engineers.

The capacity of the spillway is about 200 sec. ft. per square mile, which is about 50% greater than the peak of any known flood on the Deerfield River. In addition, as a factor of safety the reservoir has an area of 2,200 acres, which would greatly flatten any flood peak. For instance, a rise of 1 ft. in the water surface would take the maximum known flood for an hour and twenty minutes if no water were flowing down the spillway. Between the fixed concrete crest of the spillway and the top of the earth dam there is a rise of 14 ft.

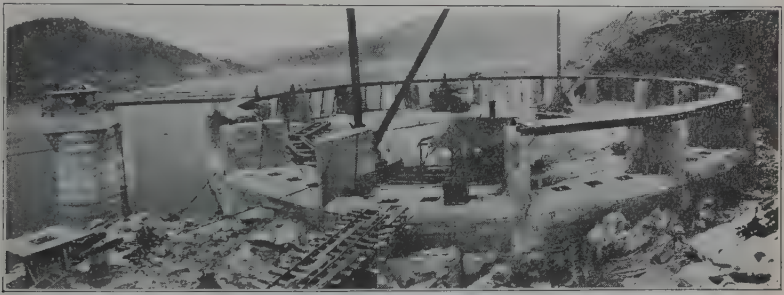


FIG. 6. — SPILLWAY WITH OUTLET CONTROL TOWER AT LEFT

The excavation for the spillway structure was included with the diversion tunnel contract. The vertical shaft was sunk with the uniform diameter called for to give the finished diameter of 22½ ft. for the lower 100 ft. This lower section was concreted to the top of the uniform section. Then a heavy platform was placed on top of this lining and the upper 70 ft. filled with muck. This gave more working space for track and operations in removing the 30,000 yards of ledge from the spillway area. Upon the completion of the general excavation at the spillway level the muck was removed from the shaft in steps, which give a working space at the respective elevations for the removal of the ledge to form the diameter, which decreased from 160 ft. down to 22½ ft. 70 ft. below the crest. A wooden form was constructed covering an area equal to one-quarter of the diameter and a height of about 60 ft. Upon completing the concrete for one quadrant this form was moved to the next thus being used four times. The concrete work under the Rollin Construction Corporation contract ended at elevation 1370. The Powe

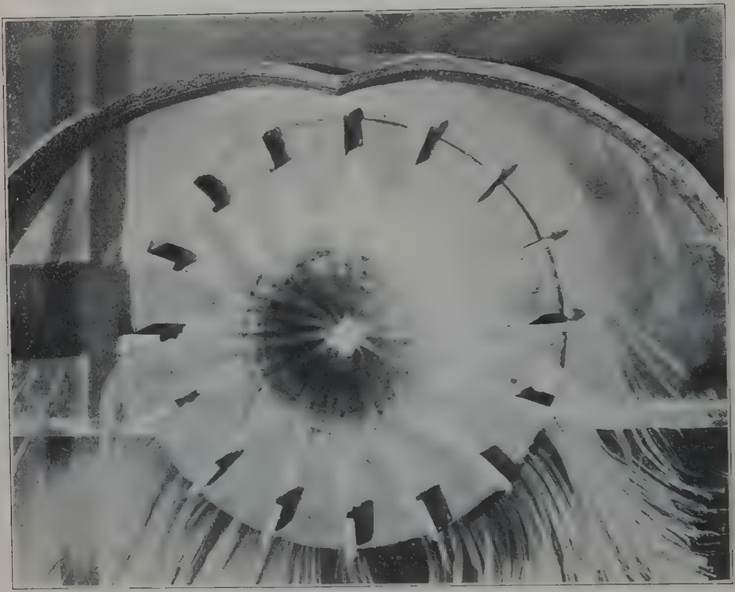


Fig. 7. — Spillway Model

Discharging water equivalent to 6 feet of depth on the crest of the full sized structure

Construction Company forces carried the concrete work above 1370 t a point approximately 1384 before the spring freshet of 1924. Th structure was allowed to pass through the spring freshet in an incompleted stage. During the summer of 1924 the concrete work at the spillway was completed, and the bridge and flashboard operating mechanism installed.

Earth Dam

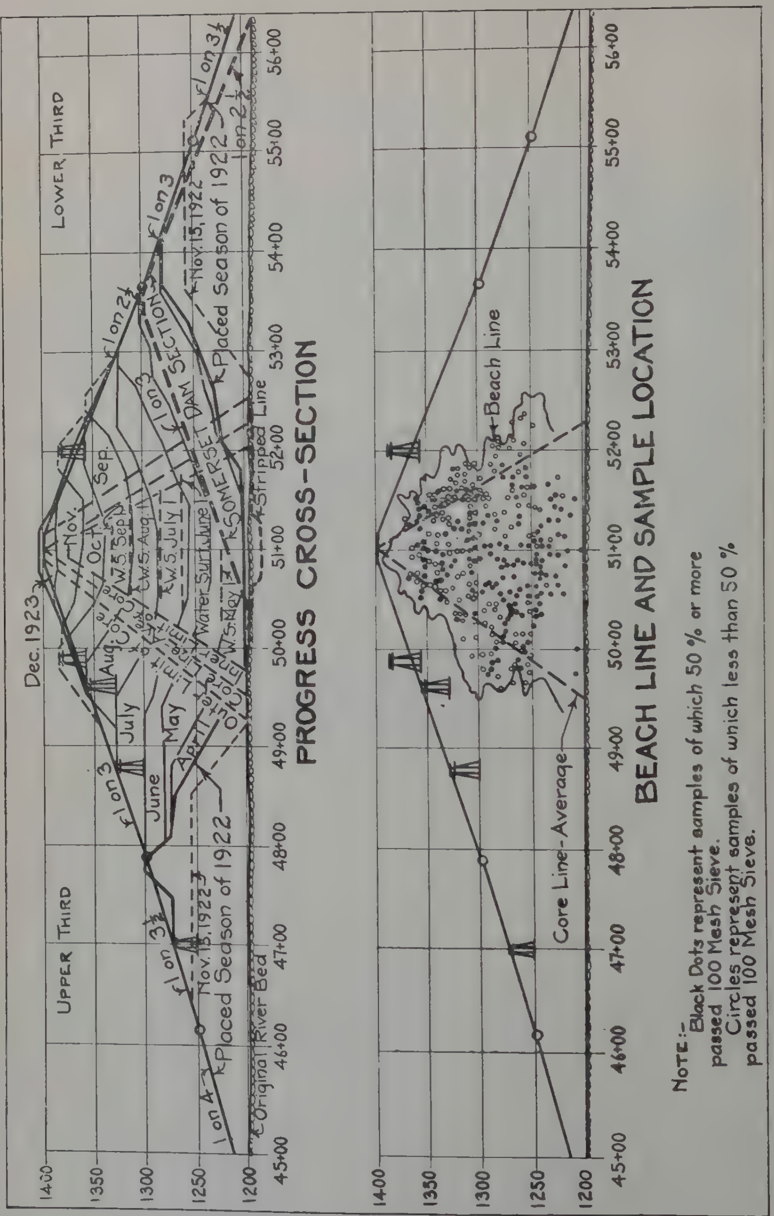
The choice as to type of dam seemed to solve itself, due to th fact that there was ledge within reasonable distance of the surface o only one side of the river. Borings which were put down in 1911 showe the ledge to drop off more than 125 ft. in the width of the river bed How much deeper the rock gorge extends has never been determined

The design of the dam was not made a matter of theoretical computations but governed by current practice and successful construction of other earth dams. The cross-section adopted was governed largely by the cross-section of the Somerset dam, which was completed in 1913 about 20 miles upstream from Davis Bridge. The upper 100 ft. of the Davis Bridge dam has the same slopes as the Somerset dam while the lower 100 ft. has flatter slopes.

There were 80 holes put down by means of well drills to determine the material underlying the dam site and the borrow pit material available. The holes at the dam site were tested at various elevations as they were driven to determine the water tightness of the material. These tests indicated a very satisfactory foundation. The material is a glacial drift with a rock flour embedding a fair number of well-scattered boulders. The holes in the borrow pit areas gave some idea as to the nature of available material and were also especially valuable in connection with laying out borrow-pit excavation. This advance information as to underlying rock in proposed borrow pit areas was a great help in forestalling any delay in shifting track and borrow pit due to unexpected ledge location. Considerable deposits of coarse gravel were found in the borrow pits and this material was used along with the more plentiful rock-flour boulder formation.

The preparation of the dam site included the removal of stumps from the total area and in the middle third the removal of top soil, the boulder layer along the river bed and adjacent banks and the excavation of a cut-off trench which was found to require a depth of 16 ft. across the bed of the river with a width of 50 ft. and narrowing as it extended up the slopes. A ledge outcrop on the left-hand side of the river extended for the full height of the dam. Loose pieces of ledge were removed within the area of the trench excavation, but ledge, where the seams were well silted up, was not removed, and no grouting or special treatment was considered necessary.

The general scheme for placing material was specified, as dumping the material in dykes upstream and downstream from the middle third and then washing these dykes with streams of water to carry the fines into a pool and thus gradually filling up the middle third. This procedure gives a dam with stable material for the outside thirds and an impervious center of the fines. It had been expected that some attention would have to be given to the selection of materials to obtain the required amount of fines for the center. As worked out, however, there were sufficient fines in the material as it came from the borrow pits as chosen by the contractor, who was governed by the most economical



NOTE:-
Black Dots represent samples of which 50 % or more passed 100 Mesh Sieve.
Circles represent samples of which less than 50 % passed 100 Mesh Sieve.

FIG. 8. — DAVIS BRIDGE EARTH DAM

handling of the required yardage. The index used as to the fitness of core material was the per cent passing a No. 100 sieve.

Mechanical Analysis of Davis Bridge Dam Core Material

Size of Mesh (mm.)	Per Cent by Weight Passing		
	Sample No. 1	Sample No. 2	Sample No. 3
4.71 (4 mesh to inch)	–	100.0	–
3.50 (6 mesh to inch)	–	99.2	100.0
2.02 (10 mesh to inch)	–	98.8	99.8
.97 (20 mesh to inch)	100.0	98.2	92.6
.44 (40 mesh to inch)	99.6	97.2	78.2
.25 (60 mesh to inch)	98.4	93.8	63.4
.15 (100 mesh to inch)	97.0	87.0	50.4
.10 (150 mesh to inch)	91.0	74.2	37.0
.07 (200 mesh to inch)	82.0	65.2	31.0
.05	76.6	61.0	28.0
.04	46.5	39.2	16.8
.022	29.3	22.9	9.4
.012	21.5	18.5	8.1
.008	17.6	12.4	4.6
.006	15.7	10.2	3.5
.004	14.5	9.1	3.0

Sample No. 1 is taken from the center of the core.

Sample No. 2 is composed of equal parts of material taken at center line, 30 ft., and 60 ft. upstream from the center line.

Sample No. 3 is a composite sample taken from six different borrow pits with coarser particles screened out.

The one feature of the project which attracted more attention than any other was the construction of the earth dam, which to date is the highest all-earth dam in the world. The bottom of the cut-off trench was elevation 1186, the river bed on center line was elevation 1200, and the top of the completed dam is elevation 1400. The crest length is 1,250 feet and the maximum width from toe to toe is 1,250 feet.

The construction problem was to handle the required yardage within a specified time. The contract for this work was let to the W. F. Carey Co., Inc., in May, 1922, and the work was to be completed by December, 1923. The first material went into the dam in June, 1922, but inasmuch as the water was not diverted until the middle of September the contractor did not have a free hand until that time. At the end of the first working season 500,000 yards had been placed, leaving 1,400,000 to be placed during the season of 1923. Material started to move again April 15, 1923, and the total yardage was in the dam before Christmas, 1923. During the five months, June to October, 1923, material went into the dam at the rate of 7,500 yards per day, which is equivalent to about 5 yards per minute, with a maximum day occurring on July 31, when 15,000 yards were placed in the dam in 24 hours.

The method of placing the material in the dam is generally known as the "Modified Hydraulic Fill Method." Material was loaded on the cars by shovels and transported by trains to the upper and lower sides of the dam, where it was dumped from the dykes, after which the fine material was washed to a central pool. The general method was the same as that employed in the construction of the Somerset dam ten years before. The details of operation varied somewhat from those at Somerset. For instance, at Somerset all the dykes were formed by first building trestles of timber and dumping from these trestles until filled and then throwing the track to the dyke. At Davis Bridge there were only five trestles used for this purpose while the rest of the dykes were formed by means of a drag line. This drag line would work out from the side of the valley by taking material from a pit into which the dirt trains would dump. It was possible to use this method because of the width of the various lifts in the lower part of the dam. As the dam section became narrow, the temporary dykes were allowed to extend outside the normal section of the dam until the pool was raised and the dyke widened after which the same drag line trimmed the slope of the dam back to the normal section. Near the top two trestles were used, and the final 15 ft at the very top of the dam was formed by the drag line handling the material into place.

The first material was placed in the upstream side of the dam by dumping from a track parallel with the river and located on the bank 50 ft. above the river bed. This fill was fanned out until the river flow was forced to the left bank. Upon completion of the diversion tunne this fill was pushed across the remaining distance and material sluiced down to the stream by means of a 750-gallon pump. This sluicing puddled the material across the boulder-covered river bed and com pletely cut off the water, thus forcing it through the diversion. A 20-ft trestle was then placed on top of this closure dyke and quickly filled giving a 70-ft. dyke which it was estimated would force any probabl flood through the tunnel.

The river bed within the middle third of the dam was cleaned ou by means of a railroad type shovel with a dinkey train removing the material to the lower third area. There proved to be about a 5-ft. layer of boulders within this area. A small shovel dug the cut-off trench. The material was handled away from this cut-off trench by means of a cableway across the valley, which dumped the skips well up the side of the

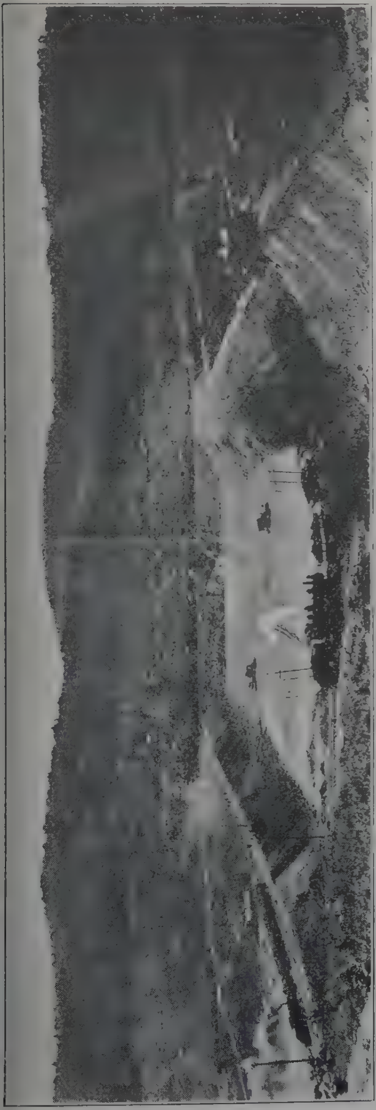


Fig. 9. — The Dam during Construction

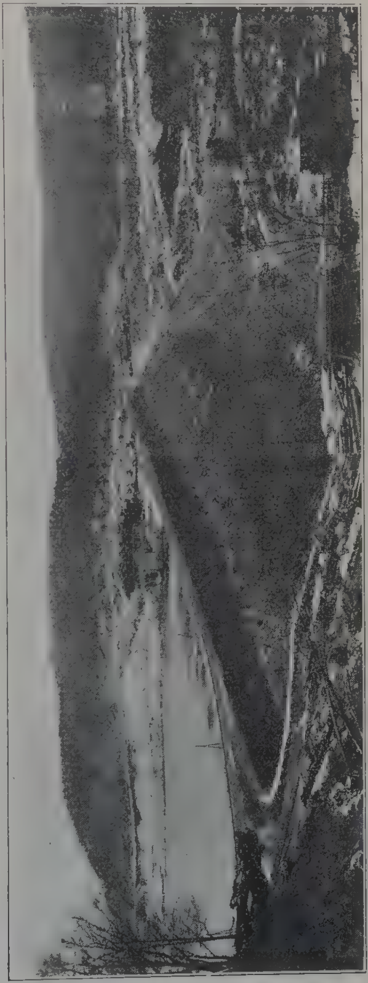


Fig. 10. — The Completed Dam

valley where the material was later handled away by the drag line. Th drag line dug the cut-off trench up the sides of the valley as the wor progressed. The cut-off trench across the river and the cleaning of th lower part of the middle third was completed on November 13, 192 to a point where water could be placed in the area between the two dyke Sluicing then started and was carried on for about a month. When th work closed down for the winter just before Christmas, water stood a an elevation of 1223, or about 40 ft. above the bottom of the cut-o trench, and there was about 6 ft. of silt in the cut-off trench. This le for the season of 1923 a height of material to be placed of 230 ft. on th center line of the dam at the deepest section. With the exception of th drag-line work and equipment required to feed it, the placing of th material was a single ten-hour shift operation.

The sluicing was done by two 750-gallon pumps at 100-pound nozz pressure direct connected to 150 h. p. motors. Each unit was mounte on a raft in the central pool and the water was used over and over. I addition a third stationary pump furnished water to several fire stream which were used in washing material away from the dumping space a track elevation. Make-up water was furnished by a pump of equ capacity set up at the edge of the river at the toe of the dam and operate as occasion demanded. Above elevation 1300 very little make-u water was required as the elevation of the pool automatically came u by the displacement due to the material washed in. Tests made durin August, 1923, under conditions which were about typical of the sluicin operation, showed that water thus sluiced carried about 8% solids as left the pump.

The building of an earth dam of this type is largely a dirt-movin operation requiring principally organization and equipment for that ty of work, coupled with sound engineering judgment in the placing o material. A great deal of credit is due the contractors on this work fo their foresight in setting up and equipping the job and the skill wi which they executed the work. Within a few days of the signing of th contract they had camp cars on the job providing living quarters fo several hundred men. Track layout was made for the use of all standa and gage equipment. Borrow pits were opened up with long runs fro the dam which permitted a track lay-out of flexibility in the operati of the dump trains. Efficient track crews were organized which mai tained the track in excellent condition and built track in new locations occasion arose. Approximately 12 miles of track were used and r located many times. The principal items of equipment used were 1 locomotives, 110 standard gage 12 and 15 yard dump cars, 6 railroa type shovels up to 5-yd. capacity, 2 whirly type shovels, locomotive crane, 150-ton drag line, and adequate machine shops and repair equipment for maintenance work. During the season of 1923 this work required a crew of 500 men.

TOWER CONTROLS FLOW TO POWER TUNNEL

The outlet control tower is a combination structure which includes the fine trash racks for the plant and the control gates. This structure is located about 300 ft. up-stream from the dam. The inside of the main part of the tower is 20 ft. in diameter and 115 ft. deep. This chamber is a dry circular cell. At the bottom there are located two 8-ft. valves of the disc-arm type operated by motors mounted directly above and supported by the valve housing. These valves are connected by means of heavy cast iron conduit with the up-stream side of the tower and the tunnel on the down-stream side. Provision has been made whereby the valve can be bulkheaded off up-stream and down-stream and the plant operated through the remaining valve with only temporary shutdown of plant. A 4-ft. steel vent pipe extends from the tunnel to the top of the tower through the circular chamber. A small tunnel extends from the bottom of the circular chamber on about a 45-degree slope in a distance of about 90 ft. to the valve chamber in the diversion tunnel downstream from the closure plug. This tunnel, which is 4 ft. by 6 ft. takes care of any seepage into the intake tower and also provides access to the lower tunnel and small by-pass gates.

The trash racks are 21 ft. wide and 110 ft. deep, extending from maximum reservoir elevation to a point 20 ft. below the minimum drawdown. The rack bars are 3 in. by 5/16 in. bars spaced 2½ in. centers. These are made up in sections and supported by 8 in. double extra heavy wrought iron pipe filled with concrete and spaced 9 ft. c. c. There is a center pier behind the racks which gives the pipe a support and middle bearing. One main object kept in mind in the design of these racks was to so design them that there would always be racks at the water surface. Because of the location of the racks in this large reservoir with the bottom about 80 ft. above the river valley, it is contemplated there will be no material amount of cleaning of the racks.

The position of the ledge foundation required the tower to be located well within the natural slope of the dam. To permit the desired minimum drawdown and to protect the lower approach to the tower from becoming clogged, a 14-ft. square conduit extends about 100 ft. upstream from the tower with its invert at the elevation of the bottom of the racks.

Under normal operation water can enter the tower through this intake and also through the racks above the conduit and down a vertical well behind the racks to the gates. When the plant is operating at the minimum draw-down stage, the water will enter the tower through the 14-ft.

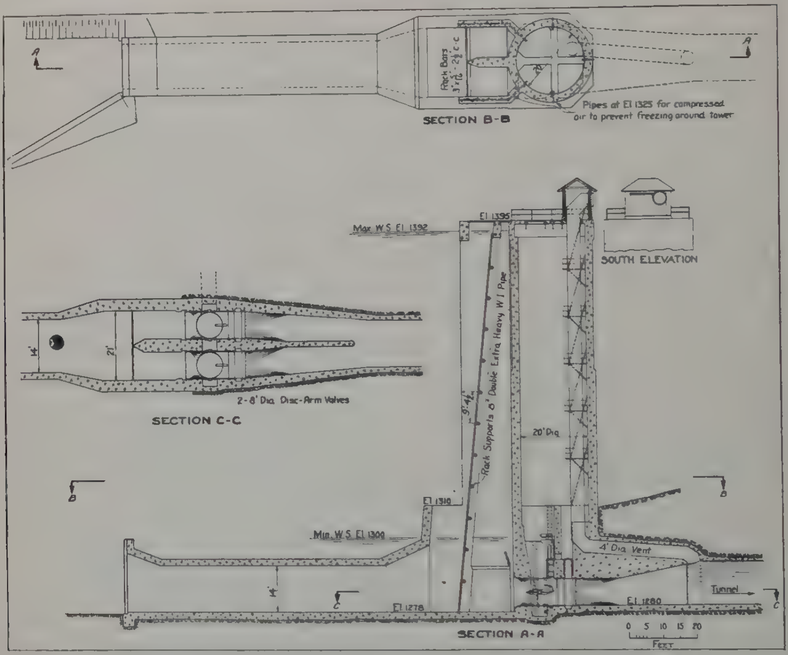


Fig. 11. — Control Tower to Power Tunnel

conduit only. A small brick house at the top of the tower gives access to the ladder and also houses the control panel for the operation of the gate mechanism. The rest of the top of the tower is covered with a concrete floor and plank bulkheads.

Power Tunnel

Between the dam and the power house the winding river covers a distance of 5 miles. The power tunnel which extends in a straight line between the two points is 2½ miles long. There is a drop in the rive between the dam and the power house of 200 ft., which, taken togethe with the head behind the dam, gives a maximum head of 390 ft. and minimum head of 300 ft.

The ledge formation in this vicinity is a mica schist of a fairly har and very tough character. Because of the very satisfactory characte of the rock an unlined tunnel was considered, but computations and estimates indicated that for the quantity of water to be handled a lined tunnel of a smaller section was more economical than a large unlined section. A lined tunnel was therefore adopted, with a minimum lining thickness of 6 in., which was considered the minimum that would be consistent with satisfactory placing. Inasmuch as the purpose of the lining was for smoothness only, the actual cross-section was fixed from a construction standpoint. With a view to giving a maximum working width at the bottom for excavation operations and a semi-circular top to give facilities for placing the lining, the section was made up with a flat bottom 14 ft. wide, sides extending vertically for 6 ft., and a semi-circular top with a radius of 7 ft., giving a section with an area of 161 sq. ft.

The elevation of the tunnel at the intake was determined by the maximum drawdown for storage. Because of a brook valley 1,000 ft. from the intake, a 4% grade was used for the first 1,000 ft. of tunnel to give the desired cover at the brook. For the remainder of the distance the slope is 0.1%. The tunnel has a maximum static head at the outlet of 155 ft. and a probable surge head of about 200 ft. A plate steel lining 14 ft. in diameter and of sufficient strength to withstand the bursting pressure under 200 ft. head was used for a distance of 320 ft. at the outlet end. The space between this ½ in. steel plate lining and the ledge has been filled with concrete.

The contract for the 2½ mile power tunnel and the excavation and concrete for the control structures at either end was let to the Mason & Hanger Co. Inc. in July, 1922. The work was laid out with a compressor plant and blacksmith shop at each end and one at the adit, which was at the half-way point. Work was carried on at four headings in two shifts per 24 hours, each shift drilling, blowing and mucking. The top heading and bench method was used, with the bench following closely the heading.

The alignment of the river made attractive an adit at the half-way point of the tunnel, from which work was carried on in two directions. This adit was driven in from the side of the valley, a distance of 800 ft., with a section of about 8 by 6 ft. The muck as it was removed from the adit was crushed and stored for use in the concrete lining. The job was started as a hand-mucking job, but due to labor difficulties a Hoar mucking machine was placed in each heading after about four months' operation. This machine materially cut down the labor requirements but did not improve progress, as the rock broke too large for the speedy operation of these machines. The final solution was a combination of machine and hand mucking to give the best progress. The average rate of progress in all headings from the beginning was 9.2 ft. per 24 hours per heading. There was considerable labor trouble and many lost shifts. Omitting time lost due to labor conditions and other difficulties the progress was 11.5 ft. per 24 hours per heading. In general, storage battery locomotives were used on muck cars although these were supplemented to some extent by gasoline locomotives and mules. As the work progressed, ventilating systems using reversible type blowers and spiral riveted pipe were installed.

The two sections were holed through about November 15, 1923, with alignment errors of 1/16 in. and 1¾ in. respectively. It required about one month to clean out, erect forms and get in shape for starting the concrete lining. On December 15 the concrete work started. The concreting plant for the lining work was located at the adit. Two sections of Blaw-Knox forms, each 150 ft. long, were set up at the adit. The concrete floor of the tunnel was first laid and the sides and arch followed. The schedule called for concreting of 150 ft. of form each 24 hours, alternating from one form to the other and working the forms toward the two portals. These assembled forms weighed about 55 tons each. It required about three hours to collapse a form, move it 150 ft. and expand it to position. Mounted on the framework of the form was the concrete gun operated by air pressure. The concrete was transported in trains of 1-yard cars from the mixing plant to the hopper above the gun and then forced into the forms by air. The concreting followed the schedule closely and was completed April 1, 1924.

SURGE TANK AND SPECIAL STEEL INTERCONNECTIONS

At the lower end of the power tunnel a plate steel lining extending about 320 ft. was assembled in sections 16 ft. long at the portal. These sections were then moved into place, connected and concrete placed between the lining and the ledge by means of a concrete air gun.

The manifold at the outlet of the power tunnel and the interconnections between the tunnel, surge tank, valves and penstocks, were located on a shelf 240 ft. above the river, cut in the ledge at this point.

A Johnson differential type surge tank, with an outside diameter of 34 ft. and a riser diameter of 8 ft., and extending 184 ft. in the air, is located at the outlet of the tunnel. The top of the surge tank is about 50 ft. above the maximum water level in the reservoir. The ring plates vary from a thickness of 1 19/32 in. at the bottom to 5/16 in. at the top, and have rivet diameters varying from 1½ in. at the bottom to ⅝ in. at the top. The tank has a bottom plate 3/8 in. in thickness for water tightness.

he tank rests upon a 3-in. bed of sand and cement which was put in dry
n a foundation of concrete over ledge. To take care of wind pressures
hile the tank is empty, which was the condition during the first winter
was erected, special care was taken with the anchorage design, result-
ng in the use of fourteen 3-in. anchor bolts extending 14 ft. into the ledge.
he surge tank was furnished and erected by the Riter-Conley Company.
t contains 420 tons and was erected between September and March
ith a force of about 15 men, totaling about 1,900 man days of 8 hours
ach.

The first design contemplated the location of the surge tank di-
ectly over the outlet of the tunnel, but a closer study of the construc-
ion program showed the desirability of locating the tank to one side.
he center of the tank is 40 ft. to one side of the tunnel lining and the
ottom of the tank is 23 ft. above the center line of the tunnel. The
4-ft. diameter tunnel lining was extended to permit the installation of a
0-ft. "T" connection to the surge tank. Beyond this point the lining
erges into a three-way manifold, which in turn is connected to 8 ft.
isc-arm valves located at the upper end of the 9-ft. penstock. Just
elow the control valves is located a specially designed 24-in. air valve
f the floating type to vent the pipes when the control valves are closed.

New Type of Pivot Valve Developed

The disc-arm type of valve used at the intake tower and at the
pper end of the penstocks was first developed for this installation by
. A. Dow, mechanical engineer of the company. It is a pivot type of
alve with the operating arm directly connected to the lower part of the
isc and operated by a stem extended through a stuffing box in the top
f the valve housing. The power may be applied either by means of a
ressure cylinder or through gears and a motor. In the case of the pen-
tock valves they are driven by motors mounted on top of the housing.
great advantage of this valve is in the connection to the bottom part
f the disc, which gives a direct application of force on that part of the
isc opposing the pressure of the water, thus resulting in a very tight
losure. These upper penstock valves can be operated either from the
ower house switchboard or at the valves. A detail of design not gen-
rally used in such valves is a sealing ring of babbitt metal in the housing.
he valves in the control tower were furnished by the S. Morgan Smith
ompany and those at the top of the penstocks by the Coffin Valve
anufacturing Company.

Penstock Erection

The 9-ft. penstocks and 14-ft. tunnel lining were furnished an erected by the Lancaster Iron Works. This same company also furnished the miscellaneous plate steel work and erected it under an extr work agreement. This included the interconnections in the vicinity o the surge tank, the assembly of the manifold, the setting up and connecting in of the valves at the upper and lower ends of the penstocks, an the assembly of the plate steel scroll cases and hydracones of the wate wheel units. The penstocks were shipped to the job knocked down an were entirely riveted at that job. The method first used was to assembl and rivet the penstocks approximately in position. Considerable diff culty was experienced with the heavy plates at the downstream end i getting them laid up tight. A field shop was then set up in which th

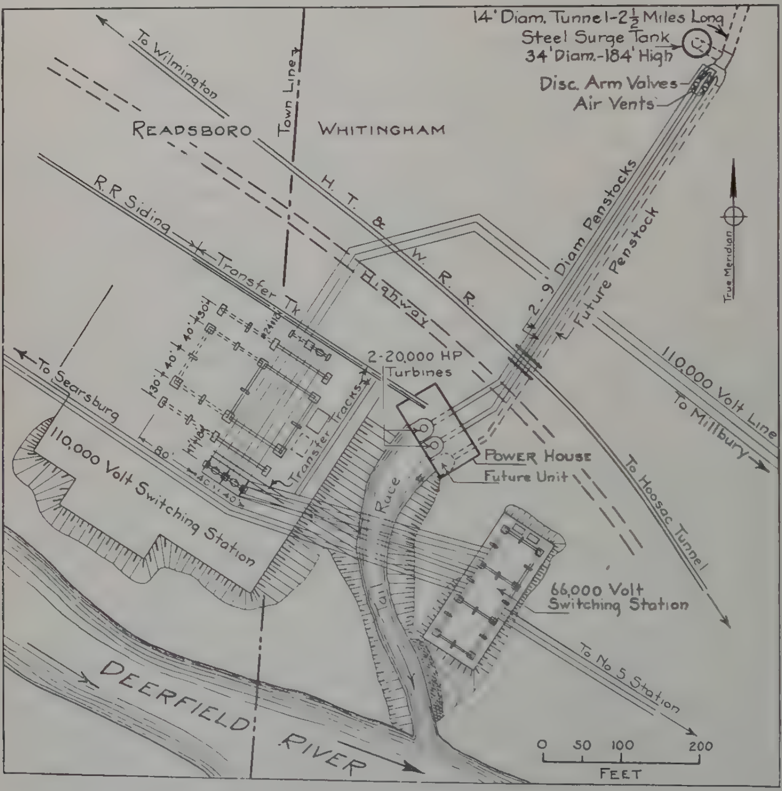


Fig. 12. — Layout in Vicinity of Power House

penstocks were assembled in two plate lengths of 16 ft. each and then moved into the trench. Much better progress was made in this way.

The penstocks are 620 ft. long and designed without expansion joints. The rivets are good for about a 40° temperature change either way from the closing temperature. The closure was made near the upper end at a temperature of about 54°. To aid in maintaining a nearly constant temperature during closure the penstock was filled with water up to the make-up joint, and the water heated by means of a railroad locomotive to a temperature of 54°. It took about 10 hours to make up the final joint on each penstock. After being tested, the penstocks were covered with earth. Butterfly valves at the lower end of the penstocks were furnished by the Allis-Chalmers Company.

Power House and Equipment

The power house has a superstructure of steel and brick construction and the usual substructure of concrete located on ledge. The downstream side of the power house contains the operating unit, in what is essentially a single floor plant; that is to say, the wheel pit is located only a few feet below the floor of the power station while the generator sets well above the floor on a concrete pedestal. This gives extremely easy access to all operating parts of the unit. The upstream side of the house has three floors, — the ground floor section containing the low-tension bus and machine shop; the mezzanine floor, the low-tension switches and storeroom; and the gallery, the switchboard room, office and the locker room.

All the high-tension equipment is located outside the power house. On the downstream side of the tailrace there is a 66,000-volt switching station which interconnects the 66,000-volt system in the valley with the 110,000-volt transformer and switching station which is located on the upstream side of the tailrace. From the 110,000-volt station the line extends to Millbury, the center of distribution.

The power house is equipped with a 60-ton Whiting crane having a 5-ton auxiliary hoist. This crane can be used to handle the 110,000-volt outdoor transformers, which can be brought inside by means of a transfer track and truck.

The units are vertical, single runner, Allis-Chalmers water wheels with General Electric 6,600 volt, 16,000 KVA. generators and direct connected exciters operating at 360 r. p. m. An envelope enclosing the generator enables the unit to take the ventilating air in through the wheel pit and discharge it outdoors during hot weather or into the building in cold weather. The turbines have a capacity of about 20,00 h. p. each under a mean head of 350 ft. Two units have been installed The point of best efficiency gives a water use for three units of abou 1,500 sec. ft. Care was taken to obtain units with water use at bes efficiency not to exceed this amount, as to exceed such a water capacit

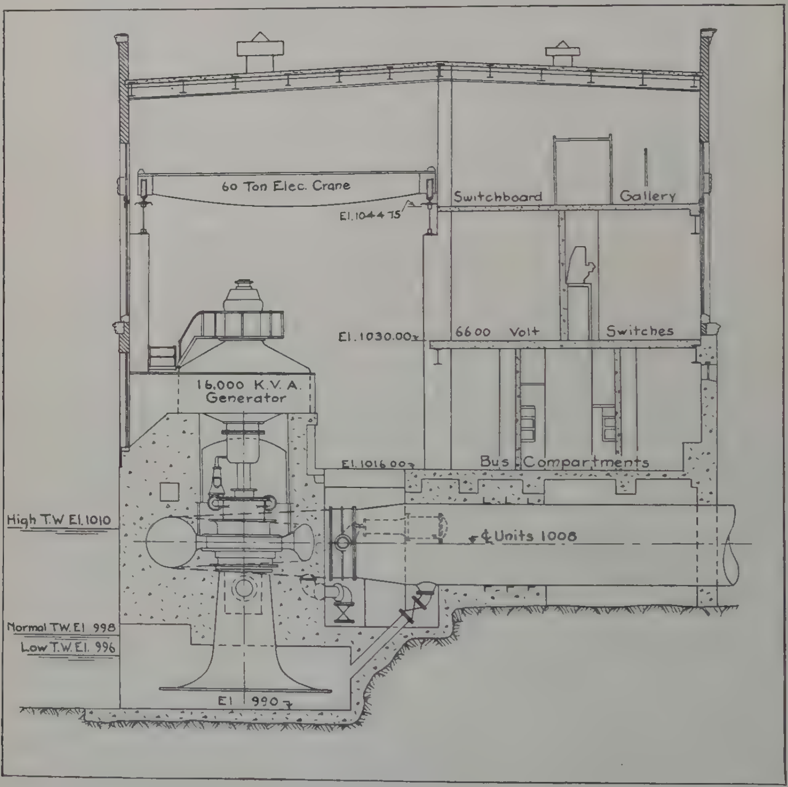


Fig. 13. — Section through Power House

was likely to decrease the overall efficiency of the plant by the increase frictional loss through the long tunnel. The wheel manufacturers mad and tested nine runners during the process of developing the design fo this installation. The scroll cases are of plate steel construction completely embedded in concrete. Before concreting, each case was teste and made tight at 260 pounds' pressure, which is about 60% more tha maximum static pressure. The cases were assembled and fitted in th hop and then shipped knocked down, and reassembled and riveted pproximately in position.

The power house substructure and miscellaneous outside work was et to L. H. Shattuck, Inc., of Manchester, N. H., the fall of 1922. Excavation was started at once and continued through the winter. In the arly spring the concrete work was started, and as soon as it was up to he lower part of the scroll cases, these were assembled in place. After he scroll cases had been tested they were concreted and the superstructure carried up. The superstructure contract was also let to L. H. Shattuck, Inc. The water wheel units were erected by the Power Construction Company under the supervision of the Allis-Chalmers Company. The generators, transformers and other heavy pieces of electrical equipment were installed by the General Electric Company, while the

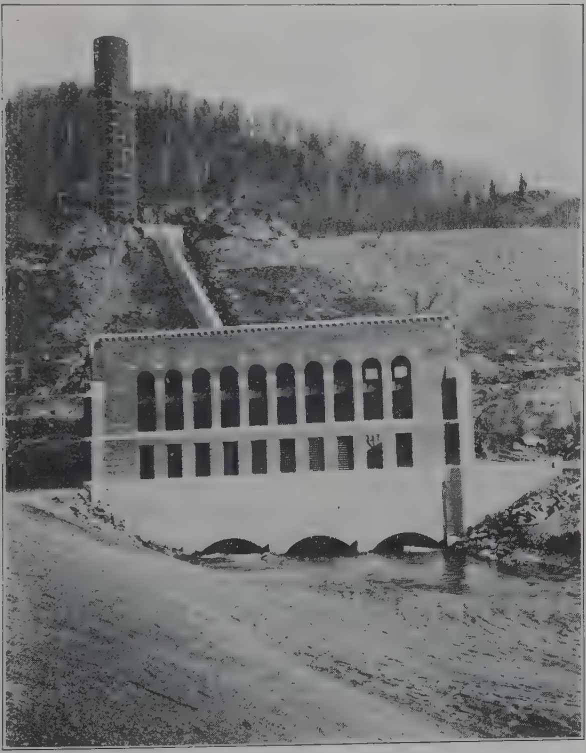


FIG. 14. — POWER HOUSE AND SURGE TANK

lighter electrical equipment, outdoor transformer and switching statio structures, conduit, etc., were installed by the Power Constructio Company.

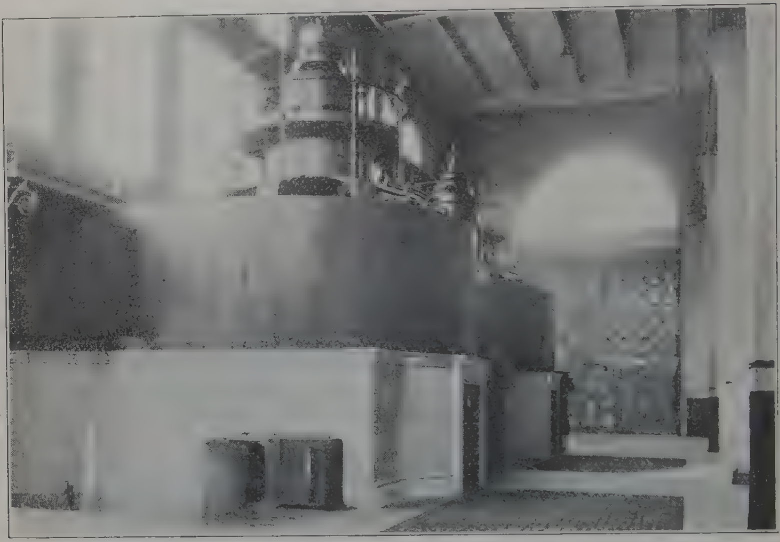


Fig. 15. — Power House Interior

Reservoir Basin and Railroad Relocation

The reservoir covers an area of about 2,200 acres, part of whic was farm land and part pasture and timber land. This area was cleare and burned by the Power Construction Company forces.

Another construction item of considerable proportions and onl incidental to the main project was the relocation of 9 miles of the Hoosa Tunnel & Wilmington Railroad. This railroad crossed the dam sit about 30 ft. above the old river bed. Surveys extending over nearly year resulted in the choice of the west side of the reservoir as the bes location for the railroad. About January 1, 1923, grading started fo this relocation and the new line put into operation early in Januar 1924. This work was carried out by the Power Construction Compan with a force of 250 men.

Before the final relocation of the road through the basin could b determined, the track had to be removed from its location at the da site. The first step was to raise the track up the side of the valley abou

00 ft. at the dam and work out the elevation in grades extending about mile up and down river to meet the old railroad grade. This was done rior to July, 1922. The road remained in this location until August, 923, when it was again moved to a point at an elevation near the top f the dam, or about 200 ft. above the edge of the river. This was accomlished by introducing a permanent switchback on the downstream ide of the dam and a temporary switchback through the borrow pit reas on the upstream side of the dam.

In December, 1923, the track was completed along the crest of the ompleted dam to the other side of the valley. Near the head of the eservoir the trains re-cross the reservoir on a trestle and bridge to he east side (using a switchback on either bank) and then pass over the ld track the remaining 2 miles to Wilmington. As is usually the case, he valley bottom was the only reasonable location for a railroad, so that o move it up the side of the valley made some rough work and heavy xcavation.

COST FIGURES

In a general paper of this nature it is impossible to give complete ost analyses. However, figures are given below of the principal items f cost which may be of interest.

Work amounting to over half the cost of the project was done by eneral contractors. Such work overlapped the work of the Power onstruction Company and in most instances the contract prices were ot indicative of the actual costs. The figures given in the accompanyng table are based on actual costs of doing the work and not on contract rices.

The total cost of the project up to the high-tension lines, including terest during construction and engineering, but exclusive of original roperties and water rights, was $9,000,000.

Principal Items of Cost

Item	Cost
1. Preliminary surveys, test pits and borings	$80,000
2. Main camp buildings and equipment	60,000
3. Camp operation (net loss over 3-year period)	20,000
4. Highway changes	150,000
5. Clearing reservoir basin	60,000
6. Railroad relocation (9 miles)	560,000
7. Temporary roads, railroad changes and sidings	70,000
8. Earth dam (1,900,000 yards)	1,900,000
9. Diversion tunnel and spillway	900,000
10. Control tower	160,000
11. Pressure tunnel (12,781 feet)	1,750,000
12. Surge tank and interconnections to tunnel and penstocks	230,000
13. Penstocks (2 installed)	170,000
14. Power house and equipment (2 units installed)	1,000,000
15. Interest during construction	530,000
16. Field engineering	135,000
17. Administration, engineering and construction fee	450,000

Notes

Item 1 — Includes about $45,000 expended for surveys and studies extendi over several years, and $35,000 for test pits and borings covering dam sites, borro pits, tunnels and power house.

Item 2 — Headquarters camp only, including capacity for 450 men.

Item 5 — Cost of clearing about 800 acres. Cost per acre, $75.

Item 7 — Includes cost of changing and operating H. T. & W. R.R. through t dam construction activities over an 18 months' period, amounting to $42,000.

Item 9 — Combined cost of handling water during construction and providi adequate spillway structure.

Item 11 — About $136 per foot of length.

Item 12 — Includes rock excavation and concrete, $50,000; steel surge ta (420 tons), $56,000; manifold and interconnecting steel, $51,000; gates and flang (2 units), $32,000.

Item 13 — Excavation, concrete and backfill, $65,000; steel, $105,000. The thi penstock will cost about $60,000.

Item 14 — The additional unit installed will cost about $220,000, giving a to unit cost of $27 for power house and equipment on a 45,000 Kw. capacity.

Item 16 — Field engineering payroll plus expenses of $11,000.

Item 17 — Covers all home office and field administration, superintendence a accounting; legal and right of way services and expenses; home office and consulti engineering; and all overhead and profit.

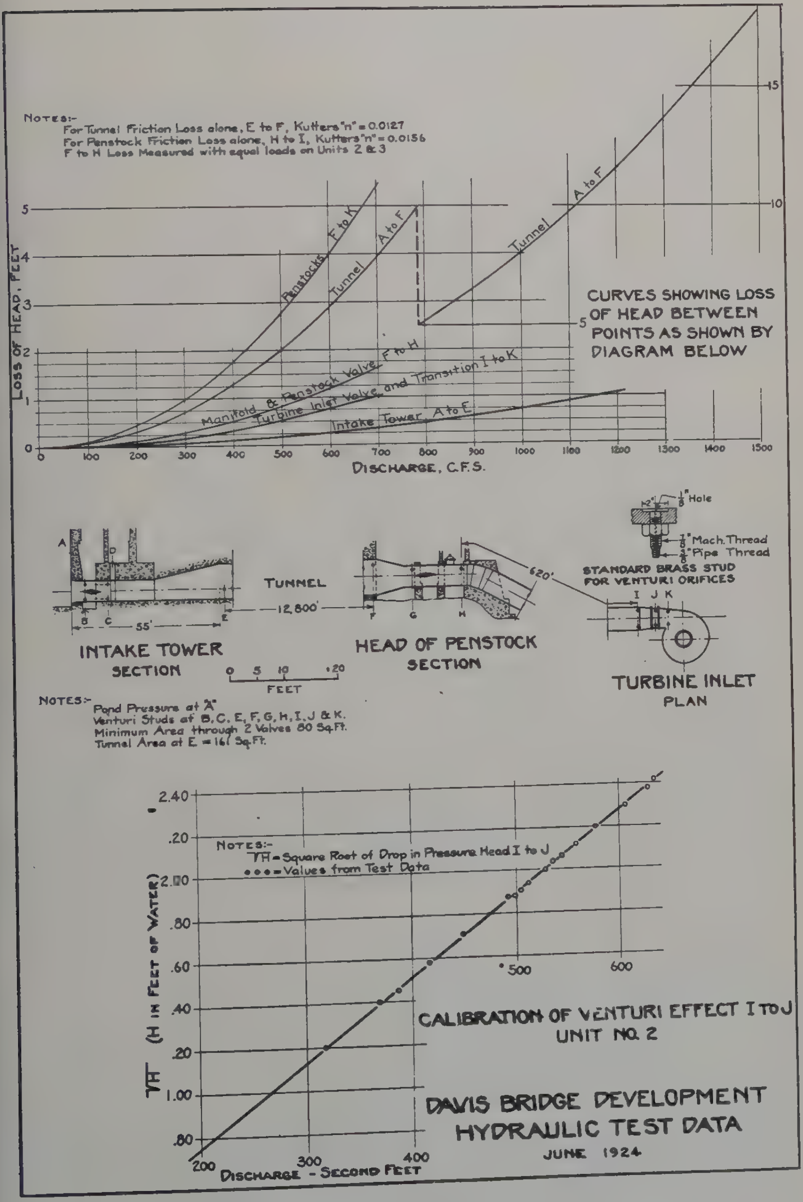

NOTES:-
For Tunnel Friction Loss alone, E to F, Kutters "n" = 0.0127
For Penstock Friction Loss alone, H to I, Kutters "n" = 0.0156
F to H Loss Measured with equal loads on Units 2 & 3
LOSS OF HEAD, FEET
0
1
2
3
4
5
10
15
Penstocks F to K
Tunnel A to F
Tunnel A to F
Manifold & Penstock Valve F to H
Turbine Inlet Valve and Transition I to K
Intake Tower A to E
CURVES SHOWING LOSS OF HEAD BETWEEN POINTS AS SHOWN BY DIAGRAM BELOW
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
DISCHARGE, C.F.S.
A
B
C
D
E
55'
INTAKE TOWER
SECTION
TUNNEL
12,800'
F
G
H
620'
HEAD OF PENSTOCK
SECTION
0
5
10
20
FEET
1/8" Hole
1/2"
7/8" Mach. Thread
3/8" Pipe Thread
STANDARD BRASS STUD FOR VENTURI ORIFICES
I
J
K
TURBINE INLET
PLAN
NOTES:-
Pond Pressure at "A"
Venturi Studs at B, C, E, F, G, H, I, J & K.
Minimum Area through 2 Valves 80 Sq. Ft.
Tunnel Area at E = 161 Sq. Ft.
2.40
.20
2.00
.80
.60
.40
.20
1.00
.80
√H (H IN FEET OF WATER)
NOTES:-
√H = Square Root of Drop in Pressure Head I to J
• • • = Values from Test Data
200
300
400
500
600
DISCHARGE - SECOND FEET
CALIBRATION OF VENTURI EFFECT I TO J
UNIT NO. 2
DAVIS BRIDGE DEVELOPMENT
HYDRAULIC TEST DATA
JUNE 1924

FIG. 16

Hydraulic Tests

Shortly after the plant went into operation in May, 1924, the No. turbine was put through a complete test. Professor C. M. Allen c Worcester Polytechnic Institute, used his "salt velocity" method i carrying out this test. In addition to obtaining the power and efficienc

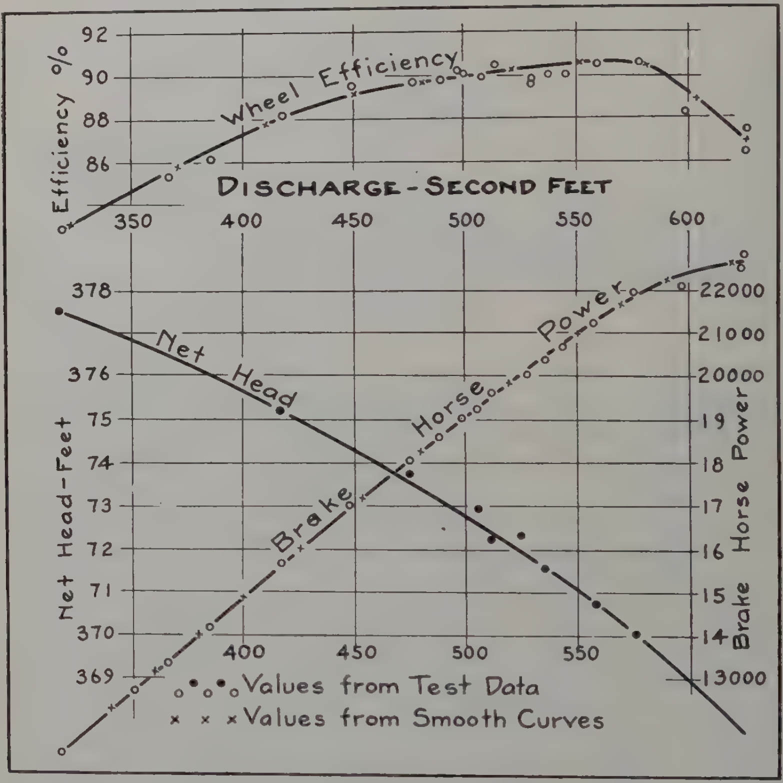


FIG. 17.—UNIT No. 2

Tested by Allen's "Salt Velocity Method." Results reduced to net heads corresponding to a common gross head of 384.5 feet with 15,000 Kw. load on Unit No. 3

characteristics of the wheel, much information has been obtained regarding head losses through intake tower, tunnel, valves and penstocks A complete Venturi rating was made of the turbine inlet valve, whic permits the accurate determination of flow through the unit at an time.

The turbine showed a maximum efficiency of 90.7% as tested unde a head some 25 ft. above the design head. The manufacturer believes the wheel will show an efficiency of 92.7% when tested under the normal head of 345 ft. The plant operates under a head varying from 390 ft. to 300 ft.

The transitional and frictional losses through the intake tower are surprisingly small. This loss is only 0.75 ft. for a 1,000 sec. ft. flow. The net minimum area in the two 8-ft. tower valves is 80 sq. ft. The area of the power tunnel section is 161 sq. ft.

The measured head loss through the 2½-mile tunnel shows the value of "n" in Kutter's formula to be 0.0127. This is a low value, but the concrete lining was placed with steel forms, resulting in a very smooth surface, and in addition the total length is one tangent and having only one break in grade.

OPERATION AND OUTPUT

The reservoir has a capacity of 5,000,000,000 cu. ft. on a draw-down of 90 ft., and it is estimated the average annual storage use will equal about 1.2 times this capacity. The Somerset Reservoir has a capacity one-half the Davis Bridge capacity. The two reservoirs combined would run this new 60,000 h. p. plant 8 hours a day for 6 months if there were no other run-off meantime.

After passing through this plant the water is used over 430 ft. of head in the company's lower Deerfield plants, and 40 ft. at the plant of the Greenfield Electric Light Company. There is an additional 310 ft. of head to be developed by the company below Davis Bridge.

The estimated average net output for this new development and its storage benefits is 136,000,000 Kw.H. per year. An interesting coincidence is the fact that the first six months' operation showed exactly this rate of output as compared with last year's output of those plants affected by storage.

Discussion

EDWIN H. ROGERS:* We are much indebted to Mr. Eaton for a most interesting and instructive lecture, and one that has been splendidly illustrated by slides. I regret to say that Mr. Henry I. Harriman, President of the New England Power Company, whom we expected to have with us this evening, was called to New York this afternoon and is therefore unable to be here.

PROF. HAROLD K. BARROWS:† The Davis Bridge power development has some especially noteworthy features. The dam is the highest constructed so far by the semi-hydraulic fill or hydraulically placed method. It is used for both power and storage, with therefore about 100 feet fluctuation in headwater level to handle.

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* President, Boston Society of Civil Engineers; Chief Engineer, Division of Metropolitan Planning, Boston, Mass.

† Consulting Engineer, Boston.

The circular spillway and outlet tunnel, while not without precedent in general arrangement, are novel in respect to large capacity. The power development represents the latest ideas in respect to types of machinery and setting and method of layout.

As regards ability to handle flood waters, the results of studies made by the speaker will perhaps be of interest. The total drainage area at the plant is 184 square miles, of which 30 square miles are practically fully controlled by the Somerset Reservoir in the headwaters of the East Branch. The Somerset Reservoir has a storage capacity corresponding to about 37 inches depth on its 30 square miles of drainage area, while the average yearly run-off is about 32 inches. Since its use, beginning with 1913, it has filled nearly to its capacity but twice, and practically no waste has occurred. Floods at Davis Bridge therefore are limited to run-off from 154 square miles of drainage area.

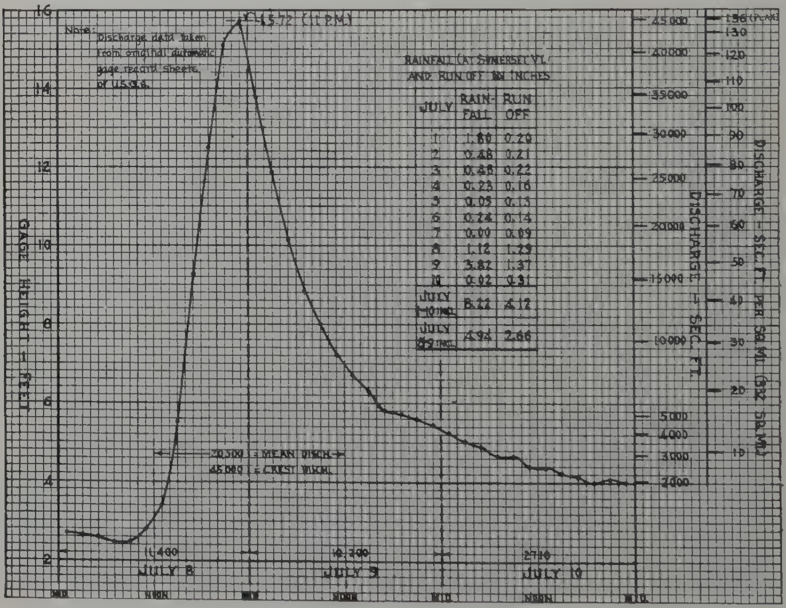

FIG. 18.—DEERFIELD RIVER AT CHARLEMONT
Flood of July, 1915

The greatest flood on the Deerfield River during the past twenty years, during most of which time records of flow have been obtained, occurred July 8 and 9, 1915. The resulting conditions at Charlemont are shown on Fig. 18. At this point the crest discharge was 45,000 sec. ft. and the maximum 24-hour discharge 20,500 sec. ft., while the rainfall at Somerset was nearly 5 inches in the two days. The unit discharge as shown is for 332 square miles, or the area at Charlemont, excluding the 30 square miles of the Somerset Reservoir, which was not filled at the time. The corresponding discharge at Davis Bridge, allowing for relative drainage areas, would have been a maximum of about 21,000 sec. ft. and an average for 24 hours of about 9,600 sec. ft.

Various studies to test the capacity of the Davis Bridge shaft spillway were made, the results of one of which are shown graphically on Fig. 19. In this case a flood curve similar in form to that of Fig. 18 was assumed, but a flood 2.5 times that of 1915, or, in other words, a crest flow of about 52,000 sec. ft. (337 sec. ft. per sq. mile) and a 24-hour average of about 24,000 sec. ft. at Davis Bridge.

Two sets of curves are shown on Fig. 19: (1) based upon an initial reservoir level at spillway crest (El. 1386), and (2) based upon an initial reservoir level at El. 1390, or with flashboards on, which, however, are assumed to be tripped shortly after the beginning of the flood day.

As will be noted, taking the limit in spillway capacity at 30,000 sec. ft., the maximum elevation of water in the reservoir would be (1) 1394.9 and (2) 1395.7 for the two different initial conditions. There would still, therefore, be a freeboard of 4 or 5 feet (the top of dam is El. 1400) for this assumed flood, which probably approaches the maximum likely to occur.

The use of the shaft spillway and tunnel in general is evidently more or less restricted to the following general conditions: —

(1) Sufficient head at the dam to permit the necessary maximum discharge without too great an area of shaft and tunnel and hence excessive cost.

(2) A limit in size of drainage area and hence of capacity required for flood discharge.

(3) A large reservoir water area to handle flood crests and enable the shaft spillway to be proportioned to take, say, only the average flow for the day, or some considerable part of that time.

A pertinent opportunity for the use of the shaft spillway also appears in the case of arch dams — not of themselves well adapted for spillway use, but usually affording conditions which would favor the use of the shaft spillway.

While the storage capacity now available on the Deerfield River is large, it does not as yet completely control flow. For the average year the spring run-off is about as follows: March, 4.8 inches; April, 8.0 inches; May (part), 3.0 inches; total, 15.8, or about 16 inches.

From El. 1310 to 1390 the total storage capacity of Davis Bridge Reservoir is about 4.6 billion cu. ft., or about 13 inches depth on 154 sq. miles. In the average year, therefore, if drawn down on March 1 the reservoir would a little more than fill during the spring high-water season if no water was drawn from it. It actually filled in about six weeks in 1924, before the plant was in operation, however. Taking into account plant use of water, evidently there will be little waste of water in the *average* year.

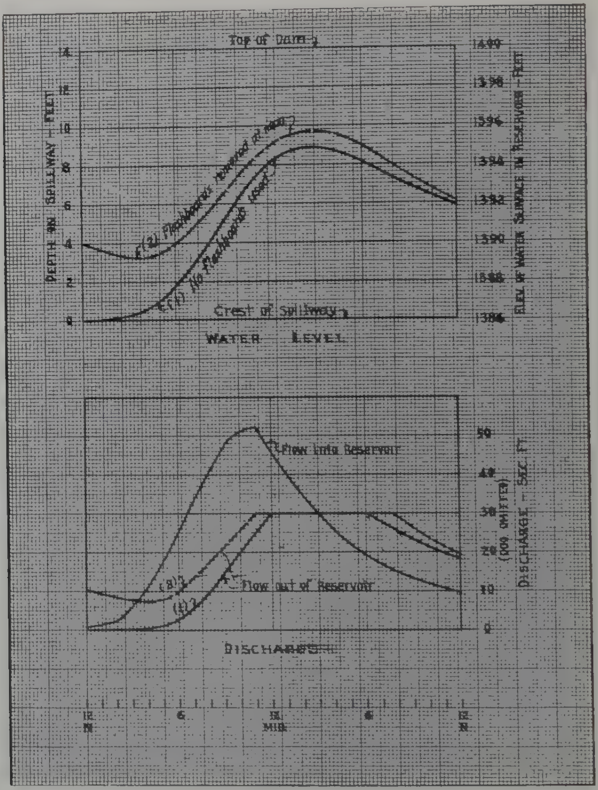

Fig. 19. — Spillway Conditions during Maximum Flood
Assumed limit in capacity of spillway equals 30,000 second feet

From another viewpoint, the storage capacity per square mile for Davis Bridge and several other power reservoirs is as follows:

Storage Reservoirs — Capacity

No.	Reservoir	River	Drainage Area (Sq. Mi.)	Capacity (Million Cu. Ft.)		Yearly Run-off (Inches)	Ratio of Storage Capacity to Yearly Run-off
				Total	Per Sq. Mi.		
1	Davis Bridge .	Deerfield .	154	4.6	30.0	32	0.41
2	Somerset .	Deerfield .	30	2.6	86.7	32	1.15
3	Nos. 1 and 2 .	Deerfield .	184	7.2	39.2	32	0.53
4	Aziscohos .	Magalloway	233	9.6	41.2	22	0.81
5	Indian Lake .	Indian .	132	5.0	38.0	28	0.59
6	Sacandaga (proposed) .	Hudson .	1,044	30.0	28.7	26	0.48

As will be seen from this table, the total storage capacity on the Deerfield corresponds to about 50 per cent of the average yearly run-off. With an extent of storage development equal to that of the Aziscohos Reservoir, for example, the total storage capacity above Davis Bridge would be about 11 billion cu. ft., as compared with the present total of 7.2 billion cu. ft., and more storage capacity on the Deerfield might be well utilized if obtainable at reasonable cost.

It is impossible to segregate the cost of storage alone at Davis Bridge, as much of the actual cost is that of the power development. On the basis of 136 million Kw.H. as the yearly average output from Davis Bridge and from the use of its stored water at plants below, the cost of power may be approximately estimated as follows: —

Fixed charges:		
	$5,877,000 @ 10% = $588,000	
	2,939,000 @ 6% = 176,000	
		$764,000
Operation		36,000
Total annual cost		$800,000

$$\frac{\$800,000}{136,000,000} = 0.60¢ \text{ per Kw.H.}$$

This is the approximate cost per Kw.H. at switchboard of the Davis Bridge and other plants.

It is to be noted that the stored water at Davis Bridge is being used at plants of the New England Power Company totalling a head of about 788 feet and future possible developments of about 300 feet more. Eventually this stored water will therefore be utilized through a head of nearly 1,100 feet. The Deerfield is obviously a stream with relatively high-power resources, combining as it does large run-off and fall, and at the same time good opportunity to store and conserve its flow.

The use of the contraction in size of penstock at entrance to the wheel spiral flume as a Venturi tube to serve as a means of estimating discharge, after rating by the salt velocity method, suggests an excellent permanent means of obtaining a record of discharge with very little trouble.

Total losses for tunnel, penstocks, etc., from Mr. Eaton's diagram appear to be:

Losses of Head — Davis Bridge Plant

SECTION	Length (Ft.)	LOSS OF HEAD (FEET)	
		$Q_1=933$ (2 Units)	$Q_1=1,400$ (3 Units)
Tunnel (A to F)	12,855	7.0	16.0
Penstocks (F to K) . . .	650±	2.4	2.4
Total	13,500±	9.4	18.4

With 2 units in operation the total loss of head is therefore about 2.7 per cent of the normal head of 350 feet, and 5.2 per cent of this with 3 units in operation.

Due to its location in the New England Company's system and its intended manner of use, the wheel capacity at the Davis Bridge plant in terms of flow used per square mile is unusually high, — that for 2 units being about 5.0 sec. ft. per square mile, and for 3 units about 7.6 sec. ft. per square mile, or the flow available about 10 per cent or less of the time during the average year. The four other plants of the Company on the Deerfield have a wheel capacity averaging about 3.8 sec. ft. per square mile, or that corresponding to the flow available about 20 per cent of the time.

The Society is much indebted to Mr. Eaton for his carefully prepared and interesting paper on the Davis Bridge project, reflecting, as it does, his intimate knowledge of its construction and design. It is clearly one of the outstanding power and storage developments among those recently completed in this country.

Arthur L. Shaw:* The provision of a spillway with a capacity capable of handling a flood with a frequency of 10,000 to 25,000 years would seem at first sight to be ultra-conservative, until one considers that this maximum *might* occur next spring, even though 25,000 years should elapse before the second occurrence. A case in point is the occurrence in 1921 of a flood of about 100-year frequency at San Antonio, Texas, within less than a year after provision for such a run-off had been recommended as the basis of design for flood prevention works.

I should like to know what provision was made in the construction of the dam for a cut-off between the earth fill of the dam and the ledge, other than clearing off the ledge and getting down to sound material?

Mr. Eaton: The dam came in contact with the ledge from the edge of the old river bed to practically the top of the dam on the left bank along the line of the cut-off trench. The ledge was thoroughly cleaned and any loose ledge removed. Ledge which was cracked to some extent, and where such cracks appeared to be well silted up, was not disturbed.

It is true that about the only leak we have is on this end of the dam 40 ft. below the top and near the junction of the surface of the dam and the original side of the valley. When the reservoir was drawn down the leak disappeared. The leakage amounted to about 6 gallons a minute. I believe this water found its way through the ledge. The water ran clear and caused no uneasiness.

Question: I should like to inquire what character of material was used in the dam.

Mr. Eaton: A good deal of the borrow pit material was loosened up ahead of the shovels by putting down well drill holes and blasting. One large borrow area was loosened up by running in horizontal "coyote" holes from the foot of the face which had been excavated and setting off some rather large blasts.

To illustrate the nature of the material in another way, I might say that a comparison of the borrow pit yardage and the final yardage in the dam indicates that the material takes up a space 3.6 per cent greater in the final dam than it originally occupied in the borrow pit. This result was unexpected. However, the work was carefully checked and rechecked, and after considerable thought I believe this is the result to be expected with this material. Like the ingredients of a good concrete, the cement is put in without materially adding to the volume already occupied by the coarser aggregates. In the case of the dam the core material, which is comparable with cement, is removed from the volume of the material as it exists in the borrow pits without reducing that volume in proportion to the new volume built up by the core. This process, I believe, is bound to result in an increased yardage with material of the nature of the Deerfield Valley material.

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* Designing Engineer, Metcalf & Eddy, Consulting Engineers, Boston, Mass.

Question: Were any means taken to determine the hydraulic gradient through the fill, by sounding?

Mr. Eaton: No such tests were made.

Question: I should like to ask how the size of the core material was controlled.

Mr. Eaton: It was controlled by the height of the pool. That is, if the samples which were taken twice a week or oftener indicated it was getting coarse, we would hold back the fills and do more sluicing, as occasion required. It was controlled by the depth and width of the pool.

Mr. E. G. Lee:* I would like to ask as an operating matter, how they regulate the capacity to take care of possible floods. I suppose you use this basin as a regulator for the stream. You have to make some provision for freshets; you have to leave a hole for it in the spring?

Mr. Eaton: Under normal operation of the reservoir we keep it down to a point well below the spillway. We aim to have it drawn down the full 90 ft. in anticipation of the spring freshets.

Mr. Lee: Can you tell approximately how often — how much you spill?

Mr. Eaton: We can draw 90 ft., using a 5,000,000,000 cu. ft. capacity, or 112,000 acre feet. We aim to have it down to the minimum point by the middle of March. We estimate we will waste water only about once in three years.

Question: How did you cover the surge tank?

Mr. Eaton: We put up a steel skeleton 3½ ft. from the tank to which was fastened nailing strips 6 inches wide. These were covered with 1-inch boards inside and out. The inside was then covered with roofing paper and the outside with corrigated zinc.

Mr. Lee: If a section of porous material extends almost from the top to the bottom of the dam, isn't that a source of weakness?

Mr. Eaton: It is a source of strength. The upstream third and the downstream third give stability, and the middle third gives tightness. If it were fine material on the outside it would slide.

Mr. Lee: What I mean is, that in the inside section there is a portion more porous than the outside layer, and wouldn't you get a head etween the inside very fine section and the outside natural soil which as not been washed?

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* Hydraulic Engineer, Central Maine Power Co., Waterville, Me.

Mr. Eaton: I think the outside material which is not washed acts s a natural drain. I don't believe there is sufficient water tightness in he outer thirds to form any barrier to the water, — that is, you have ight material in the center and porous material on either side.

Mr. Lee: I understand that the reservoir has been filled and that he only seepage that has developed through the dam was this very small ne which the speaker has mentioned.

Mr. Eaton: This was not absolutely the only seepage. There was ome seepage so small that we did not measure it at a point 30 ft. lower n elevation on the same end of the dam. Also on the right-hand side of he valley the toe of the dam rests on a little flat at an elevation 100 ft. elow the top. There is moisture at this point but not enough to run way. There had existed a swamp at this point before the dam was uilt, so that I believe the moisture as now observed comes from ground ater rather than through the dam. With these exceptions the dam is ight.

Prof. Dwight Porter:* As a matter of curiosity I would like to sk what became of the low cribwork dam which existed forty years go a little way upstream from the eastern end of the Hoosic Tunnel. s that dam still in existence?

Mr. Eaton: The site is there. The dam itself, I think, was blown ut some years ago to do away with certain taxes.

Richard A. Hale:† The dam near the Hoosic Tunnel that has ust been mentioned was designed by the late Hiram F. Mills, who was ngaged at the time on the construction of the tunnel, and the power as used for the air compressors and drills in connection with its con-truction.

I wish also to congratulate Mr. Eaton on the success of his earth am which has proved so tight and free from seepage.

The Nashua Manufacturing Company of Nashua, New Hampshire, as an interesting type of a canal earth embankment composed of gravel nd sand. It is of varying height from 4 feet to 40 feet and was built inety-six years ago. There was no sheet piling used in the original con-truction, and during this period there have been a few breaks. One of he principal breaks occurred in October, 1887, at which time about 50 feet of embankment was washed out, and the repairs were made nder the supervision of John R. Freeman, Civil Engineer, a member

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Professor Emeritus, Hydraulic and Sanitary Engineering, Mass. Inst. of Technology, Cambridge, Mass.

Engineer, Essex Company, Lawrence, Mass.

of this society, who gave a full description of the condition and repai
in the Journal of the Association of Engineering Societies, Volume VI
No. 12, Dec. 1888. A somewhat similar break occurred on March 2
1907, in which about 200 feet of embankment were washed out at a
other place. This was repaired by driving piling and building a broad
embankment than before. When the water was admitted to the cana
the water came through the filling and under the piling appearing
boiling springs on the lower side of the embankment. By throwing i
fine loam the seepage gradually decreased, and for a period of the la
fifteen years there has been no indication of seepage or leakage of an
kind. The material was of sand and gravel and was in the nature of
filter until the space was clogged with fine material. The method
construction of the Davis Bridge Dam with the excellent materia
used, and washing the fine sand into the interstices, assures a tigh
embankment with no fear of seepage.

We find a skin growth on the interior surface of the Lawrenc
Canals, which is practically water tight and assists materially in pr
venting seepage.

Mr. Eaton's method of measuring the flow by the diagrams showin
loss of head is very convenient, and is made use of in ascertaining th
quantities at times in the Lawrence mills.

PROF. D. C. JACKSON:* The Society is very fortunate in having th
interesting paper presented to it, and I also want to express my grat
fication with the admirable manner in which the subject has been pu
before us.

The constructive details of the Davis Bridge project have bee
very interestingly presented by Mr. Eaton, and in addition thereto, o
of his pictures showed the plans for the ultimate development of th
Deerfield River. This reminded me of Mr. J. B. Duke's developme
of the Catawba River in the Carolinas. It was Mr. Duke's aim
develop the Catawba River in the most economical manner to get th
full use of all the fall. He started his development earlier than M
Harriman started on the Deerfield, but they have worked with simil
ideas. We are indebted to the industry, the enterprise and courage
men like Mr. Duke and Mr. Harriman for taking a problem of this kin
in hand and working it out. I say "Mr. Harriman," but I mean,
course, Mr. Harriman and his fine group of designers, constructors a
operators all working together. In the same way, when I say Mr. Du
I include the very fine group of engineers working with him, but to M

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* Jackson & Moreland, Consulting Engineers, Boston, Mass.

uke and Mr. Harriman personally we are indebted for the imagination and courage which has inspired them to lead in these affairs.

That sort of development of the American rivers we will have to see ore of, wherever considerable drops are available, as on the Deerfield, ith a number of suitable sites for power development. Such development gives advantages, as the power plants can be operated on the load rve in such a manner as to get the best results out of the water at the ccessive sites.

Rivers developed in this manner are examples to the American ublic and a credit to American engineering and American enterprise, hich should be encouraged as adding to the prosperity of the regions which they are located.

HAROLD C. WHITMORE:* I should like to ask Mr. Eaton whether e had any difficulty with the outer third encroaching on the middle ird when he parted from the use of trestles and used drag lines in the cceeding sections? At Somerset there was difficulty with the upper ird running down on the middle third. I wonder if it happened there?

MR. EATON: I don't believe one could use a drag line on a dam less an 100 ft. high. This dam was 200 ft. high. The lower half gave a ery wide area for working space. We did use a drag line on the upper 00 ft. to some extent. In using it the material was put well outside the nes of the dam, just to keep away from the pool. After the pool was uilt up the drag line came along and rehandled the material. This was e only way we could use it on the upper 100 ft. It meant double andling of the material, but already having the machine on the ground meant speed and economy.

MR. WHITMORE: In regard to the center core. As I understand it, is of rock flour, with 25,000 yards put in at two different times, to take re of settlement. It occurred to me that the settlement must be due the fact that rock flour would flow into the loose material on either de. I was present when levels were taken some time after the building the Somerset Dam, and the results showed settlement.

MR. EATON: We have continued to take levels on the Somerset am from time to time, and while there is still settlement it is getting own to a small amount. It showed a settlement of perhaps 2½ inches, here the Davis Bridge dam showed only about 1 inch in the same relave time after completion.

Answering your first comments, I don't think the fine material ows out into the porous material. The sluicing results in the core material being carried in suspension and thus being distributed over th pool area by gradually settling out. This results in its getting thicke and thicker and a denser mud as you go down, and the whole mas keeps consolidating. As long as it kept on settling we had to keep puttin in more material. For sounding we used a 4-inch pipe 30 inches long and let it down until it stopped, and then called that the bottom, bu of course there was a lot of soft material beyond that. We started t drain off the water when we got to Elev. 1385, but the water kep running off for a month instead of a few days. This showed that th water was coming up and out and the material was going down. Th water running out was equal in volume to some 40,000 yards, which was two or three times more than the volume of the sounded pool. believe the settlement was all due to consolidating of the fine materia in the middle. There was no evidence of the fine material running int the adjacent coarser sections.

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* Engineer, Stone & Webster, Inc., Boston, Mass.

Question: Was the last material you put in, fine or coarse?

Mr. Eaton: When we got to the top we filled in with dry materia just as it came from the bank. We drew off the water and put on dr material to make a dry top to the dam. The heavy unsluiced materia might have gone down into the core some distance, perhaps 25 or 3 feet.

Richard D. Chase:* The filling or topping of the soft core wit heavier materials is interesting. A somewhat similar thing was done a San Pablo in California, at a time when it was felt that the core wa getting too much "fines", the heavier material in that case forcing ou some of the extreme "fines", giving a little more solidity to the core.

The question of whether, at the Davis Bridge dam, some of the fin material was left on the outside after the sluicing, has been raised. I seems to me that is not important. If it happens on the upstream side it would hinder the water from entering the body of the dam and dela the draining of the dam, as the pond fell. But this latter process is slow and there would be plenty of time for the water to get out of the upstrean third. On the downstream side one needs some soil to grow grass. Th only possible condition that might cause trouble would be large patche of the surface on the downstream side that were tight enough to concentrate the seepage at a few points. With the easy draining material found here in the east this seems to be a most unlikely condition.

If I could describe to you clearly the materials of which the Calaveras and San Pablo dams were made, none of you would doubt th tability of hydraulic fill dams made of the heavy and coarse materials ound almost anywhere here in the east. Out there they have one dvantage, that of location, permitting a straight hydraulic fill; that is, teep hills at either end, 500 or 1,000 feet higher than the dam. Deep oles are churned in the hillside, and the face blown toward the giants. rom the giants the materials are delivered to the faces of the dams, — ll by gravity and very convenient.

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* c/o Metropolitan District Commission, Boston.

Their difficulty is in the composition of the materials. I imagine we ould have been glad to get for "heavy material" the "fines" wasted t Davis Bridge. I have not the figures, but I doubt if I exaggerate nuch, if I say that your "fines" were to those in California as baseballs o peas, and the baseballs should be filled with lead, at that. For an ccurate description of those dams, I would refer those interested to the aper by Allen Hazen, Transactions, American Society Civil Engineers, ol. 83, 1920, page 1713. However, what they call ledge or rock is so ard that it has to be shaken down by dynamite, and it falls in chunks. hese get to the dams as pieces, and, if they are covered quickly by more, emain as chunks, as test pits show. However, if they are left to the eather for a time they fall apart and make perfectly good soil for any rop.

The "fines" also have their peculiarities. The principal one is their xtreme fineness. If as much was wasted as one would like, there would ot be much left. There is no such grading, as in our glacial drifts, from oulders to shingle, sands and then clays that will settle in water and consolidate after a reasonable time.

And yet another contradictory thing about the San Pablo "fines", vas that when samples of the core were collected in pasteboard boxes, he contents at the time looked and felt much like gray paint; of course, ot oily, but the same smooth, soft feeling between the fingers. Yet vhen these samples dried out there was left a hard block that would not reak if dropped on the floor, — in fact, almost as hard as the ledge from vhich it came.

All of which goes to show that a hydraulic fill dam can be made of ery varied materials, and the more suitable the safer the dam, and the eavier the materials, the sounder sleep nights for those in charge of the onstruction.

Mr. Shaw: Entirely aside from the water-tightness of the dam tself, it certainly must have been a really ideal foundation material not o have shown some seepage through the foundation. In very many cases vhere dams are constructed, the ground water level is affected some disance away, sometimes several miles, breaking out in springs, etc., which were not observed before. I wonder whether in raising the water level some 200 ft. above the normal elevation the general ground water conditions haven't been sufficiently changed so there is actually some seepage though not apparent in the vicinity of the dam. I should like to ask whether there have been reported to the Power Company any outbreaks of new springs at some distance from the dam, which might be traced to this source?

Mr. Eaton: No such condition was observed. Of course it is to be expected that the ground water conditions would be changed, although in putting down borings and testing for water tightness we did find that the material underneath was extremely tight. I believe what seepage does come through underneath is practically carried away by evaporation. I know of no springs which developed. Some observations were made on the side of the valley where the power tunnel was built, to see if there were any new springs as a result of that tunnel, but none were reported. No changed conditions whatever were observed.

I might say we also considered a different site for the dam at a point about 1½ miles further up the valley, and putting down borings we found gravel which was not water-tight and which was one reason for giving up that site in favor of the one used.

Mr. Whitmore: If the unit cost of placing the material was $1, which I believe was about 40 cents higher than at Somerset, was that due entirely to the change in labor rates or to other causes?

Mr. Eaton: Largely due to the change in labor rates. But this job was entirely different from that at Somerset. We had an entirely different set-up for it. It was pushed with a great deal of energy and the schedule was a very stiff one, which added to the cost. I believe if we had taken three seasons for the work instead of one and one-half the cost would have been less than $1 per cubic yard.

George S. Hewins:* I came in to hear Mr. Eaton and I feel that he has covered the ground very thoroughly. However, the core material and the forming of the core is worth more attention. The material for the dam was excavated by four or more steam shovels continuously, and these were located in different borrow pits and in different formations. There was coarse dirty gravel in one, fine river deposited silt in another, and in others the glacial drift of clays with streaks of gravel and many huge boulders and rocks. All this material, including the top soil, was sent to the dam, and there became mixed in dumping with the previous train load.

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* President, Power Construction Company, Worcester, Mass.

The inner slopes of the dam ran down steep into the pool, which was kept from 15 ft. to 30 ft. below the dumping level. These slopes were constantly washed with hydraulic streams delivered through 1½-inch and sometimes 2-inch nozzles. Each stream threw 750 gallons of water per minute under a head of 300 ft. These streams, which washed all the "fines" from the surface of the slope down into the pool, would make a very respectable brook and they dislodged as well many boulders, rocks, and the smaller stones. The slope within the pool flattened out immediately; in fact, the slope within the pool was very gradual toward the center from both sides. Pebbles and small stones and coarser ones immediately deposited themselves on the first few feet of this flat slope forming a beach, as it were, while the finer material was carried further toward the center, and the very finest, practically in suspension, was carried to the center of the pool and there finally precipitated. These very "fines" were like a volcanic soot or rock flour; they were slimy and for a very considerable depth remained in practically a liquid condition.

As an example of the condition of this core, I will tell you of an incident. When the dam was within 30 ft. of its full height we suspended a 30 ft. steel rail with a 10 ft. switch point added, making 40 ft. in all from our drag line boom, and we swung this out over the center of the pool and lowered it for the purpose of taking a sounding. This length of rail was swallowed up as fast as we lowered to below the pool surface, and while there appeared to be more resistance at the bottom, it was hardly perceptible. Some six weeks later we tried this same experiment again; however, we had reached nearly to the top and were draining off the pool, and we found that the core had consolidated by pressure so that the rail came to a stop on very firm bottom at about 20 ft. depth.

The outer thirds of the dam, which consisted of the washed material, were extremely firm and solid. Our dumping tracks were always kept right on the edge of the slope; in fact, frequently the ends of the ties overhung the break of the slope, and we safely ran trains of dirt with 60-ton locomotives out on these tracks right on the brink of the pool. Our contractors were amazed to find these banks were stable. Their previous experience which covered railroad embankment of unwashed material was always a source of worry and never permitted them to proceed in this manner. The tracks on the very edge caused a great saving in labor because the cars dumped clean down the slope, where in ordinary procedure a crew of men or a spreader would have to be used to cast the earth over the break of the slope.

During the last month of construction water was constantly rising out of the core and running off through a drain provided on the downstream side. The heavier core material was adjusting itself under th pressures of superimposed material and was forcing the water out an up. It was a slow process, but had practically stopped late in January although throughout the season of 1924 there were moist and soft spot on the downstream slope and about 40 to 50 ft. down from the top of th dam. These moist spots were there even when the reservoir had bee drawn down 60 ft. from the top.

Mr. Garrod has asked me if we were going to beautify the dam an its surroundings.

We have already planted the lower slope of the dam in rows 25 ft apart. We have used spruces, pines, fir, maple, poplar and willows in this planting, and we have besides seeded the entire area with winte rye and various grasses, so that we hope to get eventually a fine body o vegetation on the dam. I hope you all will go to see it.

Mr. Lee: Mr. Hewins brought out the point that I wanted information on. He said quite clearly that there was a beach on the inne slope of the outer banks, that is, between the center fine core and th outer material. I should think that would be a natural drain right dow the dam. I should think that water would flow right through this an be held by the outside material.

Mr. Eaton: I think Mr. Hewins stated that boulders and all sort of rock were dumped in with the material first, then the fine stuff wa sluiced to the middle, so that finally we have the fine stuff in the pool then sand, then rock and very coarse stuff outside of that which, o course, is very much more porous.

Mr. Lee: I should think that outer layer of natural material woul be more watertight.

Mr. Hewins: I think the natural outside dump is more watertigh than the coarse wash slope. The outside, however, is not even tigh enough to retard any flow of water. Any drainage from the core woul go through, but would not be objectionable or form a head.

OF GENERAL INTEREST

DORCHESTER RAPID TRANSIT EXTENSION

Work Started on First Section of $8,000,000 Project

Thomas F. Sullivan, Boston Transit Commission, a member of the Society, describes herewith the general scope of this important development.

The commencement of actual construction work on the Dorchester Rapid Transit Extension a short time ago marks the beginning of one of the most important additions to local transportation ever suggested.

The work outlined provides for the extension of third-rail train service from Andrew Square, South Boston, to Peabody Square, Ashmont, a distance of 3½ miles. From there to Mattapan Square, an additional distance of 2¾ miles, a high-speed trolley line will be constructed in the area now occupied by the Shawmut Branch Railroad, through private right of way and free from grade crossings throughout its entire length.

This addition will furnish high-speed service to and from the largest residential section in metropolitan Boston, and at the same time open up for further home building many acres of unoccupied land in the vicinity of South Dorchester, Neponset, Milton and Mattapan.

The act authorizing this work was passed in May, 1923, and the lease was signed by the Boston Elevated Railway Company on October 17, 1924. No construction work could be undertaken until the lease had been signed, but preliminary investigations, studies, plans and specifications had been made in the interim, so that it was possible to advertise the first section of this work on the day following the signing of the lease.

General Description

The plan filed in accordance with the act calls for an extension of the present Dorchester Tunnel from its terminus in Boston Street, just south of Andrew Square, by a tunnel of similar construction under Boston Street, and passing diagonally under the four main line tracks of the Boston Division of the New York, New Haven & Hartford Railroad. The tunnel then runs parallel to the railroad a short distance, passing under Dorchester Avenue, then upgrade with an open incline, bringing the tracks to the surface about 500 feet southeast of Dorchester Avenue. From this point to Columbia Road the rapid transit tracks run parallel to the New York, New Haven & Hartford right of way. From Columbia Road to Harrison Square the main line tracks of the New Haven are moved over to the east, and the rapid transit line occupies substantially the area now used by the two westerly New Haven tracks. Stations are provided at Columbia Road and Savin Hill. At Harrison Square the Shawmut Branch Railroad will be taken over and used for third-rail tracks as far as Ashmont, with stations at Fields Corner and Shawmut, and a large terminal at Ashmont. The stations at Fields Corner and Ashmont will be transfer stations for street car lines.

Beyond Ashmont, trolleys will be run over the Shawmut Branch to Mattapan until such time as further third-rail extension to this point is necessary.

Tunnel Section

The first section of the work to be built is the tunnel section, or extension of the present tunnel under Boston Street. This section is known as Section K of the Dorchester Tunnel, and is now under construction. It is a two-track subway section together with an open incline, a total length of 1,300 feet.

As the tunnel curves to the left, or east, it is necessary to cut back into part of the old tunnel for about 100 feet, removing the roof, easterly wall and center columns, and rebuilding a wider section to allow for overhang of cars. The roof of the tunnel at this section is from 14 to 22 feet below the street surface, requiring excavation to a depth of over 40 feet.

The old tunnel is of reinforced concrete and structural steel construction, the invert resting on yellow clay. The new section will be built with reinforced concrete invert and side walls, and a center wall with a flat slab reinforced concrete roof.

The tunnel section, where it runs diagonally under the four railroad tracks, will be of similar type of construction to that portion under Boston Street, except that the reinforced concrete roof is supported by steel beams encased in concrete. The roof at this point is less than 2 feet below the under side of the ties of the New Haven Railroad.

A freight siding is to be built from the main line tracks over the roof of the tunnel near Boston Street, running easterly on the south side of and parallel to the tunnel. This track is to serve industries on the south side of the rapid transit location, and will continue to Columbia Road.

The tunnel, after passing under Do chester Avenue, is on a 3 per cent upgrade, but will be roofed over for abou 50 feet beyond the street, after which i is to be an open incline of reinforce concrete construction up to the surface The deeper part of the incline will res on a clay bottom, but as the higher sections go through a strata of peat it wi be necessary to carry foundation wall down to the clay.

The work of construction on thi section at present consists largely i excavating and bridging, with a considerable amount of sewer constructio and it is being pushed day and night b the contractor, Coleman Brothers, Inc It should be substantially completed in year, during which time other section of the work should be under way.

Main Line Railroad Section beyond Tunnel

The tracks beyond the incline are t run parallel to the present railroa tracks to a point near Columbia Roa bridge, beyond which it is necessary t use the present location of the tw westerly railroad tracks and relocate th railroad tracks in the marsh land on th east, in order to disturb as little as possible private land upon which there ar dwelling houses.

An island platform station will be buil just south of Columbia Road bridge, th head house being located at the level o the bridge and containing ticket offices waiting room and the usual statio facilities. The platforms, covered to large extent by canopies, will be 350 fee long, with provisions for extension t 435 feet.

The right of way of the rapid transi tracks from the incline near Dorcheste Avenue to Harrison Square will be abou 35 feet wide with a steel wire fence ove 8 feet high on each side.

A station will be built at Savin Hi very similar in construction to that a

Columbia Road, and when these new apid transit stations are in operation, he New Haven will discontinue its present stations at these points. The bridges t Columbia Road and Savin Hill will e altered and a new bridge built at Freeport Street.

Beyond Freeport Street some private property adjacent to the railroad will ave to be taken and filled to the level f the present right of way of the railroad. This construction will carry hrough to Harrison Square, at which point the Shawmut Branch leaves the main line.

Shawmut Branch

The Shawmut Branch is to be purchased outright at a price of $950,000, reserving to the railroad certain freight connections at Milton. The branch is 4½ miles in length and is doubletracked as far as Milton. The two rapid transit tracks will run on practically the same location as the present railroad tracks, although all grade crossings to Ashmont will be abolished, necessitating a cut for about 1 mile to a maximum depth of 16 feet and requiring sewer changes and a drainage system.

Fields Corner, Shawmut and Ashmont Stations

The existing railroad station at Harrison Square will be maintained by the New Haven as at present, the next rapid transit station after Savin Hill being on the Shawmut Branch at Fields Corner. This is located on the site of the present railroad station, but being a transfer station for street cars is much larger, and, with its ramps, occupies the entire space between Dorchester Avenue and Geneva Avenue. Surface cars are brought up from and down to both Dorchester and Geneva Avenues on ramps at 5 per cent grade, with a loop for turning back cars at the easterly end. The cars load and unload on the platforms at the same level as the trains.

Shawmut Station will be built on substantially the same location as the present station, and will have side-track platforms with canopies, with entrances from Mather Street, Melville Avenue and Centre Street.

The Ashmont station will be located just south of Peabody Square, occupying not only the present location but much more land to the south. It will be the present terminal of the third-rail trains from Harvard Square, Cambridge; also the terminal for Shawmut Branch trolleys from Mattapan, and also a transfer station for street cars and motor busses. Trolleys will be brought to both platforms at the same level as the trains. The station will be enclosed and equipped as at Fields Corner and also provided with motor bus platform below.

Codman Street Yard

Train tracks will continue beyond as far as Codman Street, where the trolleys will continue on the branch to Mattapan, the train tracks turning in to the west to a yard located on Codman Street on the site of the present city of Boston paving yard. It will have a loop track around the yard and about ten storage tracks, with provision for additional tracks as required. Inspection pits will be built, as will certain yard buildings with facilities for minor repairs. Provision will be made for a street car connection on Codman Street and also for future repair shops.

Trolley Line to Mattapan

The present tracks from Codman Street to Shawmut Junction will be rebuilt for trolleys, with a station at Cedar Grove. From Shawmut Junction to Milton Station freight tracks will be on both sides of the two trolley tracks, the westerly freight track having sidings into Baker Chocolate Mills and the present freight yard. The track then continues on under Adams Street bridge to Central Avenue, where it backs diagonally across the Neponset River to the Upper Mills. A station will be provided at Milton on the site of the present station.

At present but one track will be built for trolleys beyond Milton to Mattapan, although a siding 600 feet long will be built about halfway between Central Avenue and Mattapan. The present station platforms at Central Avenue and Mattapan will be altered to provide for the trolley service, with provision for double tracking in the future.

Equipment and Cost

Substations will be built, one in the vicinity of Fields Corner and the other near Codman Street, to provide for the power distribution. The power supply will be furnished by the Elevated. Tracks, signals and all other equipment, except rolling stock, will be provided by the Transit Department. Signals will be provided on the third-rail section, but not at present on the trolley section. The estimated cost of the entire work is about $8,000,000. It is probable that portions of the line may be opened from time to time as the work proceeds, the estimated time for completing the entire project being from three and one-half to four years.

Aerial Surveying

Gerard H. Matthes, Consulting Engineer for the Fairchild Aerial Surveys, Inc., of New York, has been secured to give a series of six lectures on Aerial Surveying and Mapping to students in civil engineering at the Massachusetts Institute of Technology.

A large amount of aerial surveying is now being carried on throughout the United States, it being found particularly useful in relation to proposed projects for hydraulic developments where transmission line routes can be approximately selected without entering the property of the landowner. Maps of cities for purposes of tax assessments, determination of amount of traffic on various streets, and other similar purposes form another marked development of this work, a notable example being the recently prepared map of New York City.

Mr. Matthes was graduated from the Civil Engineering course at M. I. T. in 1895, since which time he has been actively engaged in engineering. In the last few years he has given special attention to aerial surveying, having been in charge of the survey of the Tennessee River in which this process was used. Mr. Matthes has probably done more towards developing in a scientific manner the art of aerial surveying than any one else in the country, and is, consequently, well fitted to inaugurate a course of this sort.

These lectures will be given on Fridays from January 9 to February 13, inclusive, between 11 and 12 in the morning in Room 1–190, M. I. T., Cambridge, Mass.

It is believed that Technology is the first engineering school to introduce a course of this character. Members of the Society, interested in this subject, are invited to attend the lectures.

What is the "Specific Speed" of a Water Wheel?

By Karl R. Kennison, Consulting Civil and Hydraulic Engineer, Boston.

At the request of the editor, I have endeavored in these notes to explain as briefly and concisely as possible this little-understood characteristic of water turbines.

In the case of two water wheels, placed side by side under identical conditions, same head, same diameter [Note 1], same speed, both doing their best operating at maximum efficiency, the wheel that has the higher "specific speed" will develop the greater power, not because it is any more efficient, nor because it is moving faster (actual speed same for both wheels), but because of a peculiarity of the design which enables it to make efficient use of a higher rate of discharge.

The specific speed, then, is *a measure of a wheel's ability to handle efficiently a high rate of discharge* (at a given head and speed), — fewer runners required, more power per unit.

Now of these two types side by side as described above, the one of less specific speed could by an increase in its diameter be made to discharge as much as the other and to develop just as much power; but to maintain its proper efficient [Note 2] operation, its actual speed would at the same time have to be reduced below that of the other high specific speed wheel.

The specific speed, then, is also *a measure of a wheel's ability to run at high speed* (at any given head and discharge), — an advantage for direct connection to electric generators.

This quality called specific speed, inherent in the type or design of a wheel and independent of its size, is expressed numerically as [Note 3] —

$$\frac{N\sqrt{P}}{H^{5/4}} \text{ (Formula I)}$$

The comparison previously drawn between the two wheels of different specific speeds would have been equally true if, instead of operating at best efficiency, each had been at part gate or abnormal or inefficient head. In other words, there is a different specific speed for every different condition of operation. However, the specific speed ordinarily referred to is that under normal conditions of operation, at the point of maximum efficiency.

This same quality in the design of a wheel can be expressed as [Note 4] —

$$\frac{N\sqrt{Q}}{H^{3/4}\sqrt{10}} \text{ (Formula II)}$$

In fact, this latter expression, which involves the rate of discharge instead of the power, and which therefore obviates consideration of any difference in efficiency of two types or any variation in efficiency under different operating conditions, gives a better direct comparison of this ability to handle a high rate of discharge.

Some values of specific speed are as follows:

	Specific Speed (Formula I)	Specific R. P. M. (Formula II)
Typical "Low Speed" Wheel, Holyoke Test No. 2094 . . .	46	46
Typical "High Speed" Wheel, Holyoke Test No. 2363	94	93
Propeller Type, Holyoke Test No. 2543 . .	163	163

Explanatory Notes

Note 1. — Let N = Revolutions per minute; H = Head in feet; D = Diameter in inches. Except in unusual types, the best D is very nearly independent of everything except the speed and the normal head, and can be expressed in inches as $\frac{1410\sqrt{H}}{N}$. This is because the "Specific Head" $\frac{H \times 10^7}{N^2D^2}$ of all except unusual types (like the propeller) is very nearly constant at maximum efficiency, and equals about 5.

Note 2. — It is characteristic of water turbines that when any given design or type is varied in size, the efficiency will remain the same, at the same gate opening, if N is varied inversely as D (and directly as $\sqrt{H}$).

Note 3.—Let P = Horse Power; Q = Cubic feet per second. This expression for specific speed is the result of the elimination of D by combining the relation between N, D and H stated in previous footnote, with the fact that Q varies as $\sqrt{H}$ and as D^2.

Note 4.—I have called this convenient characteristic the "Specific R. P. M." It is numerically equal to the specific speed at 88 per cent efficiency, and is its equivalent for all practical purposes.

Builds Ten Miles of 60 and 56 Inch Steel Pipe Line

The water supply of the Metropolitan Water District is obtained mainly from the Wachusett watershed. From the reservoirs at Southborough and Framingham it is drawn as required for consumption through the Sudbury and Weston aqueducts. The average daily consumption from the Metropolitan Water Works is 125,000,000 gallons, or 96 gallons per capita.

The Sudbury Aqueduct has a capacity of about 100,000,000 gallons per day and discharges at elevation 134 into Chestnut Hill Reservoir, from which the water is pumped and distributed to the higher parts of the District. The Weston Aqueduct will have a capacity of about 300,000,000 gallons per day when all three of the siphon pipe lines are laid, but only one line is now in service. Water from this aqueduct is delivered at elevation 200 at the terminal chamber in Weston, near the Commonwealth Avenue bridge over the Charles River. From the terminal chamber water is now delivered to the District by gravity through two cast-iron supply mains, one 48 inches and the other 60 inches in diameter.

An additional supply main of 60-inch steel pipe, for a distance of about 5 miles, and 56-inch pipe for another 5 miles, is now under construction at an estimated cost of $1,800,000. The first section, including 11,400 feet of 60-inch lock-bar steel pipe, has been completed at a cost of about $330,000. Work is now in progress on the second section, including the laying of 15,400 feet of 60-inch lock-bar steel pipe through the city of Waltham, under contract with the C. & R. Construction Company, amounting to nearly $600,000. Work is also under way on the third section, which includes the laying of 17,600 feet of 56-inch lock-bar steel pipe in Belmont and Arlington, by the T. A. Gillespie Company, amounting to about $520,000. Contract plans are now being prepared for the last section, about 7,000 feet long, extending from Arlington Centre to the connection with the two existing 30-inch mains at the junction of the Mystic Valley and Alewife Brook Parkways. From this point it is proposed to lay a 48-inch pipe line through Boston Avenue to connect with the existing 48-inch main in College Avenue, Medford.

The contractors have developed interesting methods for handling the construction of these large steel pipe lines, and they would no doubt be glad to have any members of the Society visit the jobs.

Rubber Pavement in Boston

Mr. Edgar S. Dorr, who has given considerable study to the question of rubber pavement, has prepared the following article describing briefly the experimental installations of rubber paving blocks in Boston, together with a résumé of the developments in this type of paving up to the present time.

Rubber pavement is still in the development stage, and but little uniformity has as yet appeared. In general the forms in which it has been made may e divided into two classes: slabs and locks. Within the allowable limits of his article it is impossible to do more han to state the objects sought to be ttained, the difficulties to be overcome, nd the present state of the art.

The objectives are two: to make an deal pavement, and to find use for the ast amount of rubber junk now accumuating in the form of worn automobile ires.

Rubber makes an ideal pavement. It s noiseless, light in weight, permits no ibration on road or bridge, is not slipery for horses or automobiles even when vet, and its durability is extraordinary. ts lightness and non-vibratory features nake it valuable for steel bridges and articularly for draw-spans, for which ts elasticity also is a merit.

It is obvious that the second objecive, *i.e.*, to furnish a market for the ubber junk, is attained; the old tires re ground or macerated, mixed with ew rubber, as will be described later, nd become the material of the block.

The difficulties in the way of the genral use of the rubber pavement are two: o devise a block which will remain in lace (or a secure attachment of the lock to concrete base of road or wooden eck of bridge), and to reduce the cost which is comparatively high and is a bar o its introduction.

In England the effort has been to make block of wood, concrete, or rubber comosition, with a high-grade rubber cap, bout one-half inch, vulcanized on, and he block laid like any other block pavenent. These have met with indifferent uccess, the caps becoming detached rom the wood or concrete bodies under raffic. The block, 3 inches thick, with rubber composition body and corruated interlocking sides, is the best of his type, and much of it has been laid, nd to the best of the writer's knowledge as given satisfaction; yet this was the lock which was laid around the Cenotaph in London, and failed through crawling. The explanation given is that it was laid on a wet mortar bed and the traffic admitted too soon, which is probably correct. It is, moreover, expensive — $16 per square yard in London.

Experimental Installations at Boston

In America the effort has been to economize by making thin blocks, 1 to 1½ inches thick, and attaching by spiking to wood, or by protuberances on the under side to be embedded in wet mortar on concrete base. Experimental patches of both these types of blocks have been laid in Boston. The first is 12 x 6 inches and 1 inch thick, with spiking flaps projecting from one side and one end at the base of the block and fitting into corresponding recesses in the bases of adjoining blocks, so that the blocks fit very closely at the surface. These were laid with a rubber-asphalt cement applied hot to the wooden deck of the Northern Avenue bridge, screw-spikes driven through the flaps, and the joints filled with the same cement. This was laid last May, and the result is perfectly satisfactory under very heavy traffic of all kinds, and demonstrates the qualities claimed for rubber pavement. This block was made by the Wright Brothers of Racine, Wisconsin.

The other type of block, made by the Boston Woven Hose Company, has been recently laid on Harrison Avenue at the entrance to the City Hospital. It is 12 x 6 x 1½ inches thick with six protuberances, resembling black piano keys, under the base; these are pushed into a 1-inch bed of wet mortar on the concrete base, and the joints filled with an asphaltic cement. This is the first attempt to lay rubber blocks on a street; it has not been down long enough to show results. The attachments to the base will, without doubt, prevent crawling; whether the adhesion of the mortar will be sufficient to prevent rolling up and out under heavy truck wheels starting and stopping, or displacement by frost, remains to be seen.

Another block, or slab, rather, has been developed in Boston. It is 36 x 18 x 1½ inches in thickness. It is molded with conical holes to admit of screw-spikes being driven, the holes to be subsequently closed with conical plugs cemented in. It has a novel feature, — a heavy wire mesh embedded close to the bottom. The reason for it is that in the earlier London types, which were all large slabs, secured only at the curbs, it was found that the under surface had worn faster than the upper. The theory to fit this phenomenon is that there was a lateral movement or flow of the rubber under the point of intense pressure of the wheel, and that caused the concrete base to abrade the under surface of the slab. This slab is adapted to bridge paving as is the Racine block, but has not yet had a trial.

"Racine" Rubber Blocks on Michigan Avenue Bridge, Chicago.

The problem of attachment is a mechanical one, and will be solved for street paving as it now is for bridge paving. The other difficulty, high first cost, is of an economic and business nature. Economy requires that as large a proportion of old stock and as little of new rubber should be used as practicable. The Racine block contains 38 per cent of new rubber; the slab last described, 15 to 20 per cent, and it appears sound, although not yet tested by use So there is considerable latitude in the matter of proportions. The Racine block (on Northern Avenue bridge) is certainly amply strong. It shows no signs of wear yet, although accidentally subjected to a very severe test. A freight car of the Union Freight Railroad, which has a track on the bridge, jumped the track and ran across the rubber pavement One would have expected that the sharp flange of the car wheel would have cut through the 1-inch rubber blocks, but they show no sign of injury, although grooves were cut in the planking on each side of the rubber.

Future Possibilities

The price of new rubber is more likely to decline than to advance as new plantations come into bearing, but this effec is partly offset by the rubber junk coming to have some value on account of the new demand, whereas it has no value now Reduction in the thickness of the block toward which there is already a tendency, may be carried further. There i no necessity for a thick block of thi slow-wearing material. The greates economy will come through quantity production, when the demand warrant it. These blocks are vulcanized unde 2,500 pounds' pressure per square inc and 400° F. temperature. The plan cost is high and quantity production i necessary for economy.

But at best it will always be a high priced pavement compared with woode block or asphalt, the two smooth pave ients with which it is properly com- arable — probably two or three times s much. But first cost is not the gov- rning factor; yearly cost should be, hat is, first cost divided by endurance. The endurance is surprising; the early English slab pavements laid in 1870, of which some was taken for renewal after ifty years, showed 3/16-inch wear on he average on the top surface. In a vestern city a rubber pavement, taken ip for use elsewhere after eleven years' ervice, showed 1/8-inch wear. The con- lusion to be derived is, therefore, that ubber pavement costing two or three imes as much as other smooth pave- nents bids fair to last a corresponding ength of time, and is therefore no more xpensive in the long run.

The present state of the art is that the English continue to lay considerable uantities of rubber blocks, which indicates satisfaction; that several types have been developed in America, two of which at least are now practical, for use on bridges, and are the best pavements known for them; that the Racine block has already come into use quite extensively in the Middle West for railroad grade crossings in place of plank which lasts but a short time, and has been used for the whole of the Michigan Avenue bridge in Chicago, both roadway and sidewalks, and that many firms including the Goodyear Company are actively engaged in developing rubber blocks.

It may therefore be confidently predicted that when a block with a practical bond for use on concrete bases shall be demonstrated, rubber block pavements will be laid in the public streets, particularly where quiet is desirable.

PROCEEDINGS

MINUTES OF MEETINGS

Boston Society of Civil Engineers

December 17, 1924. — A regular meeting of the Boston Society of Civil Engineers was held today in Chipman Hall, Tremont Temple, Boston, and was called to order by the President, Edwin H. Rogers, at 7.15 p.m. There were 170 members and guests present.

The minutes of the previous meeting were approved as printed in the November Journal.

The Secretary announced the names of those elected to membership by the Board of Government at its November and December meetings.

November 19, 1924. *Members:* Charles E. Breitbeil, James L. Crandall, Horace A. Del Grosso, Mortimer B. A. Hooper, John F. Pierce, Arthur A. Shurtleff, Scott Keith,* Eugene Mirabelli.* *Associate:* Harry Lewis. *Junior:* Dean P. Tsagaris.

December 17, 1924. *Members:* Ray L. Coolidge, Edgar W. Davis, Harold R. Kepner, George C. Houser.* *Juniors:* Edmund A. Baratta, George E. Bertini, Moses L. Bowers, Francis V. Britt, Daniel C. Frost, Harold B. Frye, George A. Melcher, Carl H. Nelson, Morris Rubin, George W. Sawin, Waldimir Semenyna, Chester D. Shepherd, Lermond F. Simonds, James W. Urquhart, John J. Vertic, Carl A. Wolfrum.

The President announced the death of four members of the Society: Andrew J. Gavett, died May 25, 1924; Walter E. Parker, died October 26, 1924; Clarence H. Rooks, died December 3, 1924; George C. Whipple, died November 27, 1924, and stated that committees would be appointed to prepare memoirs.

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* Transferred from grade of Junior.

Mr. Rogers then introduced Mr. Arthur C. Eaton, Hydraulic Engineer, Power Construction Co., Worcester, Mass., who gave an illustrated talk on the "Davis Bridge Hydro-Electric Development of the New England Power Company." Following Mr. Eaton's paper, which was presented in a most interesting manner, there was a general discussion in which a number of members and guests took part. The paper, together with the discussion, is published in the January number of the JOURNAL.

Meeting adjourned at 9.30 P.M. after Mr. Rogers had expressed the Society's appreciation of Mr. Eaton's courtesy in preparing and presenting this paper.

J. B. BABCOCK, *Secretary.*

DESIGNERS SECTION

DECEMBER 10, 1924. — The regular December meeting of the Designers Section of the Boston Society of Civil Engineers was called to order at 6.10 P.M. in the Affiliation Rooms.

The report of the November meeting was read and approved.

After a few remarks by Chairman Edward H. Cameron the meeting was turned over to Prof. Sutherland of Massachusetts Institute of Technology. The general subject for the evening was "The 1924 Joint Committee Report on Concrete." This report was divided into six parts and taken up as follows: Prof. Dean Peabody, Jr., of M. I. T., "the mixing and proportioning of concrete"; Charles E. Nichols, of Stone & Webster, Inc., "the design of slabs, beams and columns;" Prof. Hale Sutherland, of M. I. T., "shear and diagonal tension;" Walter W. Clifford, of Clifford & Roeblad, "bond stress and anchorage"; Mark Linenthal, Consulting Engineer, "flat slabs"; and B. A. Rich, of Rich, Bigelow & Tirrell, "column footings and retaining walls."

A letter from J. R. Worcester was read. The meeting was then open to discussion. A representative of the Portland Cement Association spoke, and Prof. Lewis J. Johnson, of Harvard, took an active part in the discussion. Manuals of the Portland Cement Association were distributed at the beginning of the meeting.

There were 150 members and visitors present. The meeting adjourned at 8.35 P.M.

WALDO F. PIKE, *Clerk.*

SANITARY SECTION

DECEMBER 11, 1924. — A special dinner meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Engineers' Club at 6 o'clock on the above date.

Following the dinner, the meeting was called to order by Chairman Gordon M. Fair. Following announcement of the death of Prof. George C. Whipple, the members rose and stood in silence in respect to his memory.

Short talks were then given by all members of the Committee on Sewage Disposal of the Engineering Board of Review of the Sanitary District, except Mr. James H. Fuertes, who was unable to be present. The other members of the Committee are as follows: John H. Gregory, Professor of Civil and Sanitary Engineering, Johns Hopkins University, Baltimore; T. Chalkley Hatton, Chief Engineer, Milwaukee Sewerage Commission; Clarence W. Hubbell, Consulting Engineer, Detroit, Mich.; Anson Marston, Dean of Engineering, Iowa State College, Ames, Iowa; Asa E. Phillips, Consulting Engineer, Washington, D. C.; and Harrison P. Eddy, Consulting Engineer, Boston, Mass.

The meeting adjourned at 8.45 o'clock.

H. P. EDDY, Jr., *Clerk.*

JANUARY 7, 1925. — A meeting of the Sanitary Section was held on the above date in the Library of the Affiliated Technical Societies of Boston, being called to order at 7.15 P.M. by the Chairman Gordon M. Fair. Following the reading of the minutes of the previous meeting Mr. Thomas McKenzie, town engineer o Westerly, R. I., read an illustrated pape on the "Sewerage System of the Town o Westerly," in which he also described th sewage-treatment works.

The attendance was 48. This is th

rst meeting of the Section which has een held at 7.15 instead of the customary our of 7.45. The consensus of opinion eems to be that this was a more popular our.

H. P. Eddy, Jr., *Clerk*.

APPLICATIONS FOR MEMBERSHIP

[January 15, 1925.]

The By-Laws provide that the Board of Government shall consider applications or membership with reference to the ligibility of each candidate for admission nd shall determine the proper grade of nembership to which he is entitled.

The Board must depend largely upon he members of the Society for the infornation which will enable it to arrive at a ust conclusion. Every member is thereore urged to communicate promptly any acts in relation to the personal character r professional reputation and experience f the candidates which will assist the Board in its consideration. Communicaions relating to applicants are considered y the Board as strictly confidential.

The fact that applicants give the names f certain members as reference does not ecessarily mean that such members enlorse the candidate.

The Board of Government will not conider applications until the expiration of wenty (20) days from the date given.

For Admission

Bean, Paul Leonard, Auburn, Me. Age 43, b. Saco, Maine.) Experience in lowage survey, Union Water Power Company; computer, street railway; lraftsman, Phoenix Bridge Company; nstructor, civil engineering, 1909–12, ssistant professor, stream gauging, hylrographic surveys; 1912–15, associate rofessor of civil engineering, all at Uniersity of Maine; 1915–19, chief engineer, Maine Public Utilities Commission; 1919–4, member of firm Sawyer & Bean; 1924 o date, agent and engineer, Union Water Power Company. Refers to H. K. Barrows, H. S. Boardman, C. H. Pierce, H. M. Turner.

Bowie, John Henderson, Milton, Mass. (Age 21, b. Hyde Park, Mass.) Is a student at Northeastern University, and while attending college has been employed as rodman in the Engineering Department of the town of Brookline. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Callahan, Daniel Edward, Lynn, Mass. (Age 26, b. Lynn, Mass.) Graduate of Tufts College, 1921, degree B.S. in civil engineering. From September, 1922 to January, 1924, asst. supt. and supt. in charge of building; from January–March, 1924, employed in the Water Division of the state; and from March, 1924, to date, with the Boston Elevated as assistant engineer in the maintenance department. Refers to E. L. Lockman, F. A. Mahoney, A. T. Sprague, H. M. Steward.

Connor, Raymond Francis, Medford, Mass. (Age 24, b. Medford, Mass.) Graduate of Tufts College Engineering School in 1922. Has been employed by the Boston Elevated since July, 1922, in the Engineering Department. Refers to Robinson Abbott, W. J. Alcott, Jr., H. C. Hartwell, E. L. Lockman, E. H. Rockwell.

Conroy, Thomas J., Roslindale, Mass. (Age 21, b. Boston, Mass.) Graduate of Wentworth Institute, architectural construction, in 1924. July–October, 1924, was employed as draftsman by the Pennsylvania State Highway Department; from November, 1924, to date employed by the Edison Electric Illuminating Company in the Street Engineering Department. Refers to E. L. Johnson, E. A. Varney.

Davis, Edward Leslie, Jr., Swampscott, Mass. (Age 23, b. Swampscott, Mass.) Attended Mass. Inst. Tech. from October, 1920, to January 1, 1923, and from this date to the present has been a student at Northeastern University. During attendance at the University he has been employed by Bradford & Weed; by John Dyer of Melrose; and by the County Engineer of Essex County. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Fuller, Linn C., Wollaston, Mass. (Age 19, b. Hartland, Me.) Graduate of Wentworth Institute, architectural construction, and is at present studying on concrete design at Franklin Union (nights). Is employed by the A. S. Smith Iron Works, Chelsea. Refers to H. A. Gray, B. E. Sullivan, E. A. Varney.

Graustein, Edward A., West Medford, Mass. (Age 34, b. Cambridge, Mass.) Graduate of Harvard College with degree A.B., and spent one year in Harvard Graduate School of Applied Science, and one year at Mass. Inst. Tech. Spent three summers at Harvard Engineering Camp in various capacities. Was engaged in hydro-electric work and transmission line construction with Turners Falls Power and Electric Company. His experience has been very largely in the hydro-electric field, and he is now in business for himself, hoping to specialize in water power. Refers to G. H. Brazer, H. J. Hughes, W. F. Pike, A. T. Safford, H. M. Turner, J. F. Vaughan.

Leaver, Raymond J., Lawrence, Mass. (Age 29, b. Lawrence, Mass.) He has been connected with the Arlington Mills, Lawrence, Mass., since 1911, where he is now chief draftsman, designer and engineer in charge of construction and maintenance. Was nineteen months overseas in the 25th Regiment of U. S. Engineers. Is now with the Arlington Mills in the position named above. Refers to J. R. Baldwin, Joseph Fitch, R. A. Hale, W. D. Hartshorne, F. H. Mitchell.

Loefquist, Gunnar Emil, Cambridge, Mass. (Age 34, b. Stockholm, Sweden.) Technical graduate of colleges in Sweden. Has been assistant engineer in three different companies in Sweden, and is now employed by W. A. Mason & Son Company, Cambridge, Mass., as assistant engineer. Refers to L. M. Hastings, G. F. Hooker, C. A. Mason, F. J. Maynard, G. N. Watson.

Niechcay, Frank K., Boston, Mass. (Age 25, b. Czernowitz, Austria.) Is a student at Northeastern University on the co-operative plan. Was in the service for nine months during the World War. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Shields, Wilfred Henry, Dorcheste Mass. (Age 24, b. Dorchester, Mass.) a senior at Northeastern University, a has been employed as chainman by t Boston & Albany Railroad; transitma by United Electric Railways Compan and at present is employed by Whitma & Howard. Refers to H. B. Alvord, C. Ell, J. W. Ingalls, W. E. Nightingale.

Smith, William M., Cambridge, Mas (Age 28, b. Sussex, N. B.) Educated public schools of Cambridge, and tw years private tutoring in mathemati and mechanical drawing. 1913–191 rodman and transitman with W. Mason & Son Company; 1917–191 Engineering Corps, U. S. A.; 1919–192 assistant engineer with W. A. Mason Son Company and a member of this fir from 1922 to date. Refers to L. Hastings, G. F. Hooker, C. A. Maso F. J. Maynard, G. N. Watson.

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BOOK REVIEWS

"Electrical Engineering," by L. A. Hazeltine, Professor of Electrical Engineering, Stevens Institute of Technology; The MacMillan Company, 1924, 625 pages. Included in the Engineering Science Series, edited by Dugald C. Jackson and Earle R. Hedrick.

In this book a successful attempt has been made to present in compact form and convenient arrangement the fundamental principles of electrical engineering. Beginning with the underlying physical relations and laws of energy, the phenomena of electrical conduction, electrostatics and electromagnetics are clearly set forth. Transient currents and electric waves are then treated. The author next passes to the subject of conduction in gases and electrolytes as embraced in modern electron engineering. Electrical measuring instruments, followed by a discussion of measurements, serve as an ntroduction to sections devoted to direct-current and synchronous machinery. The book takes up the laws of induction and rotating and fixed apparatus dependent upon them, after which the principles of transmission, distribution and electrical communication are elucidated.

Throughout this book the quantitative method of attack has been consistently maintained, and the use of what might be called engineering mathematics is continuous. A vast amount of fundamental nformation is here presented in a form exceptionally useful to the professional electrical engineer and serious student of electrical phenomena.

"Structural Engineering — Fundamental Properties of Materials," by George Fillmore Swain, Gordon McKay, Professor of Civil Engineering, Harvard University. First edition. McGraw-Hill Book Company, Inc., New York. 200 pages.

This work contains a large amount of valuable engineering information concerning structural materials, condensed into a small volume. The fundamental properties of the principal materials are presented in a clear and pleasing manner.

The text of the present book is closely connected with the author's "Strength of Materials" recently published, and the reason for not publishing them together was to avoid making the earlier volume too bulky. It is intended that one shall supplement the other to a considerable extent.

The author's own words convey very clearly the scope and use of this book. He states that it is written to emphasize "the fundamental properties, the constitution and physical structure, the importance and effect of various ingredients, the effect of different treatments, and the significance of the specifications used to secure the desired properties in the material to be employed."

That it is not intended to take the place of the more complete treatises on materials is shown clearly by the fact that Professor Swain includes, at the heading of nearly every chapter, specific references to chapters in other works in which more detailed information may be found if desired. Such a practice in a book of this kind is admirable, as it makes the book not only a valuable text in itself, but also a reliable source of reference material.

"Accounting and Business Methods for Contractors," by Charles F. Dingman. First edition. McGraw-Hill Book Company, Inc., New York. 175 pages. Pocket size.

Mr. Contractor, of large or small business, did you "make money" during the year 1924? Did you make as much money as you expected to make? When you had finished these jobs did you actually make the "paper profit" that you had figured? If your answer is *no* to any of these questions, do you *know* why you failed?

A study of the above-titled book and two other books by Mr. Dingman, — "Estimating Building Costs" and "Plan Reading and Quantity Surveying," — and the application of the principles and methods outlined will help greatly in capturing that ofttimes elusive "paper profit."

Because a business is comparatively small it does not follow that the tried and proved methods used by many large firms are not applicable. The following chapter headings show the scope of the book: Timekeeping, Labor Cost Finding, Material Cost Finding, General Bookkeeping on the Job, Purchasing, Subcontracts, Insurance, Banking Affairs, Contract Forms.

For a contractor starting or reorganizing a business this book is most valuable. To a contractor with an established business there are methods explained and form given that would add to the efficiency o the field and main offices and to the valu of his records.

All the methods and forms given migh not be adopted by any one business, a the extreme of too much detail and to many finely divided records, particularl in keeping cost of labor, is as much to b avoided as too little detail. The book i recommended for thoughtful studiou reading.

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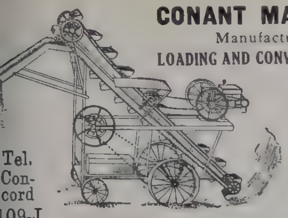

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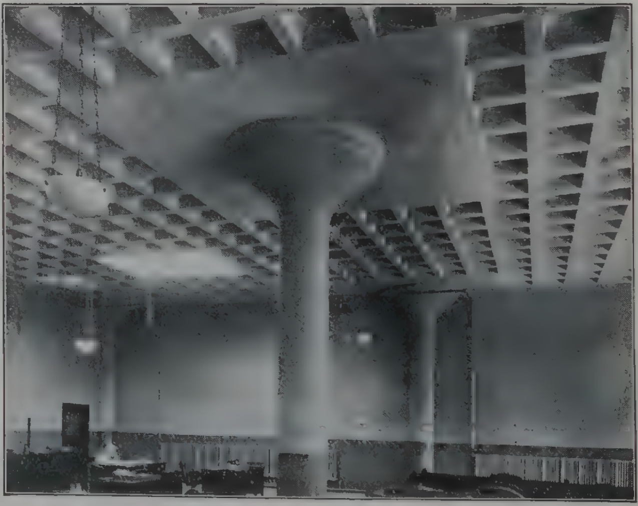

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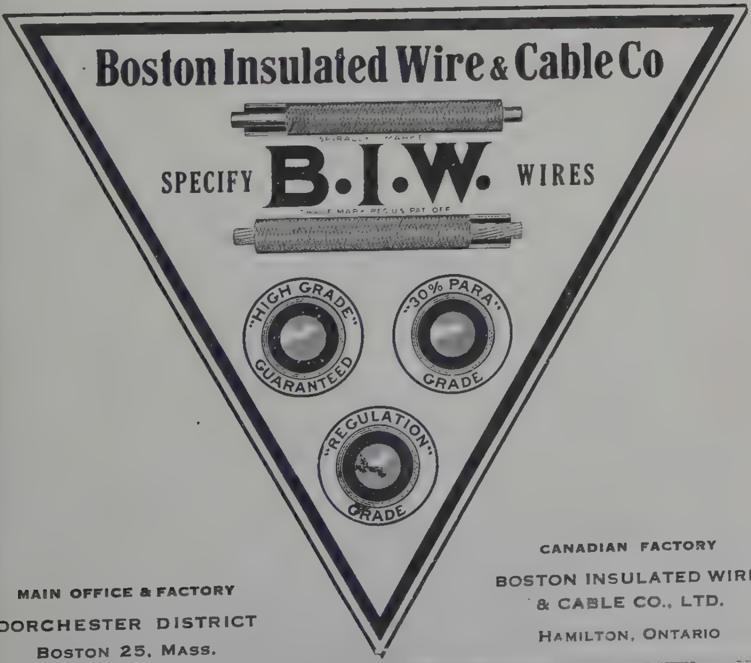

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